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Characteristics of Residual Insecticides *Toxic to the House Fly*

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CONTENTS

Exposure of flies to surfaces treated with insecticides is quickly accomplished with the cages shown here. The cages are inverted and stacked, with a treated panel on each cage; then the sliding metal panel in each cage is withdrawn to allow flies in the cage to have direct contact with the treated panel.

Characteristics of RESIDUAL INSECTICIDES *Toxic to the House Fly*

WILLIS N. BRUCE

FOR centuries the house fly, *Musca domestica* Linnaeus, has been an annoying, disease-carrying menace to man and other animals. Spillman & Haushalter (1887) demonstrated the house fly to be a possible vector of *Bacillus tuberculosis*. Nuttal (1899) showed that *Spirillum cholerae* and staphylococci could be transmitted by house flies. Esten & Mason (1908) determined by counts that on an average a house fly carried 1,250,000 pathogenic organisms on its exterior surface. In a publication upon the typhoid or house fly, Felt (1909) estimated the indirect losses to our vital assets incurred by typhoid at 350 million dollars annually. Also, he suggested that house flies can spread plague, trachoma, and septicemic diseases. Howard (1909) wrote that the annual cost of screening against house flies in the United States is over 10 million dollars. Later, Herms (1911) stated that the public pays over 2 million dollars for fly traps, sticky fly paper, poisons, and sprays each year. Pipkin (1942) proved that *Musca domestica* can carry *Endamoeba histolytica* on its external surface and in its digestive system long enough to effect transmission. The evidence presented above, along with the list in Metcalf & Flint (1939) of 20 disease pathogens carried by flies, is more than sufficient reason to brand the house fly as potentially the animal most dangerous to human beings within the borders of the United States.

Although the house fly is important as an annoyance and as a vector of disease, it causes no direct injury to man or other animals. It is not equipped to bite or sting or in itself to cause disease by any of its life stages.

Pathogenic organisms may be carried on the surface of the fly's body, adhering to the numerous hairs, sticky pulvilli, wings, and mouthparts, or they may be carried in the alimentary canal to be spread by defecation or regurgitation. The filthy feeding and breeding habits of flies make inevitable the mechanical transmission of disease by these insects.

In Illinois, the house fly usually winters in the pupal or larval stage; a few adults live through the winter in protected places. The female fly deposits 2 to 21 batches of 100 to 150 eggs in manure or any other suitable decomposing organic matter. The whole life cycle through egg, larva, pupa to adult may be completed in 6 to 20 days. In Illinois there are usually 10 to 12 generations of house flies each summer. These facts account for the enormous build-up of flies that usually occurs during August or September in the temperate zone.

INSECTICIDES USED

The five chemicals described below are the principal insecticides used in the study reported here.

DDT (designation derived from the generic name dichloro-diphenyl-trichloroethane) was first synthesized by Zeidler (1874). Chemically this material is known as 2,2′ bis (parachlorophenyl) 1,1,1-trichloroethane. The technical grade that was used in the experiments reported here consisted of a mixture of para, para′; para, ortho; and ortho, ortho′ isomers. Pure DDT may be described as an odorless, stable, crystalline solid that is soluble in most organic solvents and insoluble in water. The first United States patent on it was granted to Paul Müller in 1943

for the Geigy Company Inc., of New York, N. Y. Although Wiesmann (1943) first described its usefulness as a residual insecticide for the control of house flies, Annand (1944) suggests that it was tested by Müller on house flies in 1940.

Rhothane D-3, or 2,2′ bis (parachlorophenyl) 1,1-dichloroethane, a material closely related to DDT, was found by Müller and others to be of less promise as an insecticide than DDT. However, the Rohm & Haas Company was convinced it possessed some valuable insecticidal properties and consequently obtained a patent for its manufacture. *Rhothane D-3* (also known as TDE, DDD, and D3) is soluble in the same solvents as DDT; it has a higher vapor pressure and a lower melting point than DDT.

Chlordan or 1,2,4,5,6,7,8,8-octachloro-4,7-methano-3a,4,7,7a-tetrahydroindane was first synthesized by Dr. Julius Hyman and first discussed as an insecticide by Kearns, Ingle, & Metcalf (1945), who showed that when tested in a Peet-Grady chamber chlordan was three to four times as toxic to flies as DDT. In the highly refined state chlordan is a light yellow, viscous, nearly odorless liquid that is soluble in aliphatic, aromatic, and chlorinated hydrocarbons. It is infinitely soluble in kerosene, deobase, and no. 9 oil. Such solubility is not true of DDT, *Rhothane D-3*, or hexachlorocyclohexane, mentioned below. Chlordan has a specific gravity of 1.61 and weighs about 13.5 pounds per gallon.

The chemical 1,2,3,4,5,6-hexachlorocyclohexane was described by Slade (1945) as an insecticide with outstanding properties. According to Slade, Michael Faraday in 1825 first described the synthesis of hexachlorocyclohexane (referred to by Slade as Gammexane or 666) by the reaction of chlorine with benzene in the presence of sunlight. In 1943, Slade found the gamma isomer to be the toxic principle in the crude hexachlorocyclohexane. Usually the technical material has 10 to 12 per cent by weight of the gamma isomer. Pure gamma hexachlorocyclohexane has a faint musty odor, is a colorless crystalline material melting at 112.5 degrees C., and is soluble in most organic solvents.

Toxaphene, a technical chlorinated camphene with an approximate empirical formula $C_{10}H_{10}Cl_8$, is a soft, waxy, light yellow material that melts at 65 to 90 degrees C. and has a density of 1.6. It is readily soluble in most organic solvents and insoluble in water. *Toxaphene*, formerly known as Hercules *Synthetic 3956*, is produced by the Hercules Powder Company of Wilmington, Delaware. Stearns (1947) indicates that *Toxaphene* has some promise as a household insecticide.

In addition to the insecticides described above are several on which preliminary studies were made.

PURPOSE OF STUDY

The purpose of this study was to obtain pertinent information about the residual insecticidal value of chlorinated hydrocarbons applied to various surfaces that had been exposed to different field conditions. The investigations conducted in 1943 at Orlando, Florida, by Lindquist *et al.* (1944) showed DDT to possess a high degree of residual toxicity to the house fly. They also showed a difference in toxicity of DDT when applied to painted and to unpainted wood. The need for the study reported here became apparent to the author when certain of his field applications of residual toxicants failed to effect adequate insect control. The results of this study, it is hoped, may serve as a guide to persons who are seeking to control insects through applications of residual insecticides and who are concerned with residues on plants.

ACKNOWLEDGMENTS

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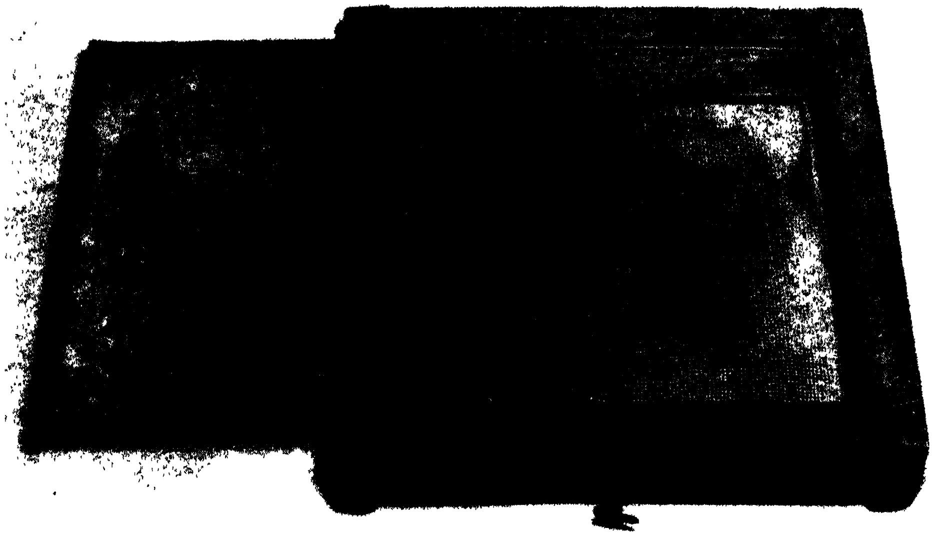

Fig. 1.—Exposure cage used in the experiments. As shown here, the cage is inverted, and the sliding panel is partly withdrawn.

Entomologist of the Illinois Natural History Survey, for constructive criticism of the manuscript.

TESTING PROCEDURE

A versatile flat exposure cage, fig. 1, was designed by the writer for use in the field, fig. 2, and for laboratory tests described below. The method of exposing cut film that photographers employ suggested its design. Made of a three-fourths inch white pine frame 8½ inches square by 1¾ inches deep, the cage is covered on one side by 16-mesh screen wire and fitted on the other side with a sliding panel of manila paper or sheet metal. It has an interior space of about 75 cubic inches. More than 300 cages of this design were required for the tests.

All house flies used in the tests were reared according to the accepted Peet-Grady method (Anonymous 1946). About 120 pupae (2.2–2.4 grams) were placed in each exposure cage via the sliding panel, fig. 1. Flies were supplied with food, a mixture of milk and water, by means of a small shell vial fitted with a piece of cheesecloth. A shell vial was inverted upon the screen top of each cage, permitting the adult flies to feed by contact, fig. 3. In each test of an insecticide, adult flies were exposed to a treated surface on their second day of oviposition, and on the following day the mortality counts were made.

The exposure process was simple. First the cage was placed on a clean, flat board and then the sliding panel was removed momentarily to allow the empty pupal cases and other debris to fall out. With the panel replaced, the cage was moved and secured to the treated surface. The sliding panel was then removed to allow the flies to have direct contact with the treated surface for the desired exposure period. Obviously because of the house flies' habit of seeking the ceiling as a resting place when illumination is reduced, preliminary tests under average laboratory lighting indicated that best replication was obtained by inverting the cages (screen side down) during the exposure, frontispiece. However, in bright light and at temperatures between 80 and 90 degrees F. there was little difference between results from the upright and the inverted position during exposure.

The treatment of the selected surfaces was simple and yet apparently reliable. In the early tests, the quantity of prepared insecticide, containing 1 per cent of the residual toxicant by weight, was measured with a pipette and spread evenly over the surface with the aid of a small brush, fig. 4. Additional water or solvent was used to wash the residue from the brush onto the surface.

In later tests the deposits were obtained by means of a 6-foot stainless steel settling spray tower, fig. 5. A Tattersfield spray apparatus was fitted with smaller openings in order to reduce the particle size to 2–50 microns range. Even distribution and good replication (less than 2 per cent variation among deposits) were obtained with this apparatus, fig. 4.

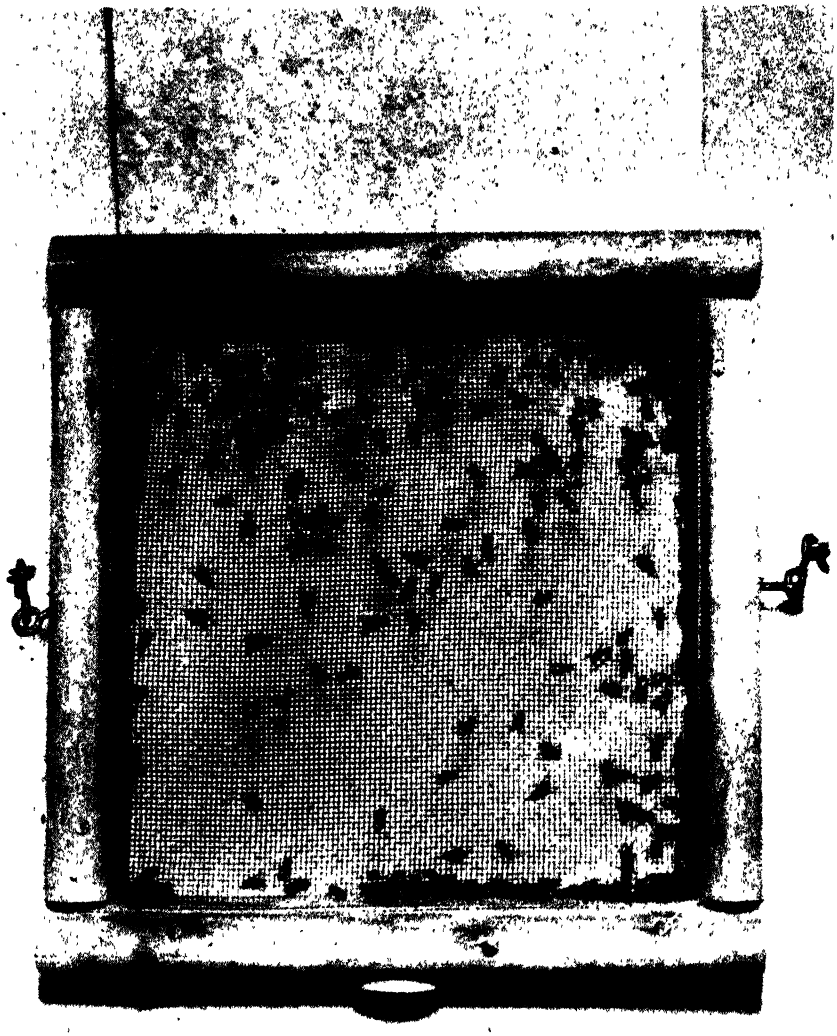

Fig. 2.—Practical method (not used in the experiments) of testing the toxicity of wall surfaces treated with residual insecticides. The exposure cage is hooked to the treated wall, and the metal panel is withdrawn to give flies in the cage direct contact with the wall for a given period of time.

The following are some of the common formulations of the concentrates used in making 1 per cent sprays. Formulations other than these are indicated in the discussion of individual tests.

A. Emulsions:
1. 62% chlordan + 5% *Atlox 1045-A* + 33% no. 9 oil by volume.
2. 25% DDT, *Toxaphene,* gamma isomer of hexachlorocyclohexane or *Rhothane D-3* + 70% *PD 544-C* (solvent known also as *Sovacide 544-C*) + 2% emulsifier *B-1956* and 3% *Triton X-155* by weight.

B. Water-wettable powders: 50% by weight of toxicant + 2% wetting agent (*Triton X-100*) + 48% by weight of *Cherokee* clay.

C. Oil solutions: 1.0% by weight of toxicant per volume of no. 9 oil.

After each test the cages were decontaminated in a mild KOH solution, washed thoroughly in soapy water, and allowed to dry in the sun for about 2 days. The manila sliding panels were discarded after being used once. With this procedure no contamination difficulties were met.

Fig. 3.—Method of feeding flies in exposure cage. A shell vial filled with milk and stoppered with one layer of cheesecloth is inverted and placed on the screen top of the exposure cage.

Experiment 1: *Exposure Time for Knockdown and Mortality.*—In an experiment designed to reveal the exposure times necessary to give comparable mortalities for the five principal materials tested, as well as to indicate the relative initial surface toxicity and speed of knockdown of flies, lots of 100 to 120 flies each were exposed to deposits of 50 mg. per square foot (538 mg. per square meter) of glass for each of three replicates.

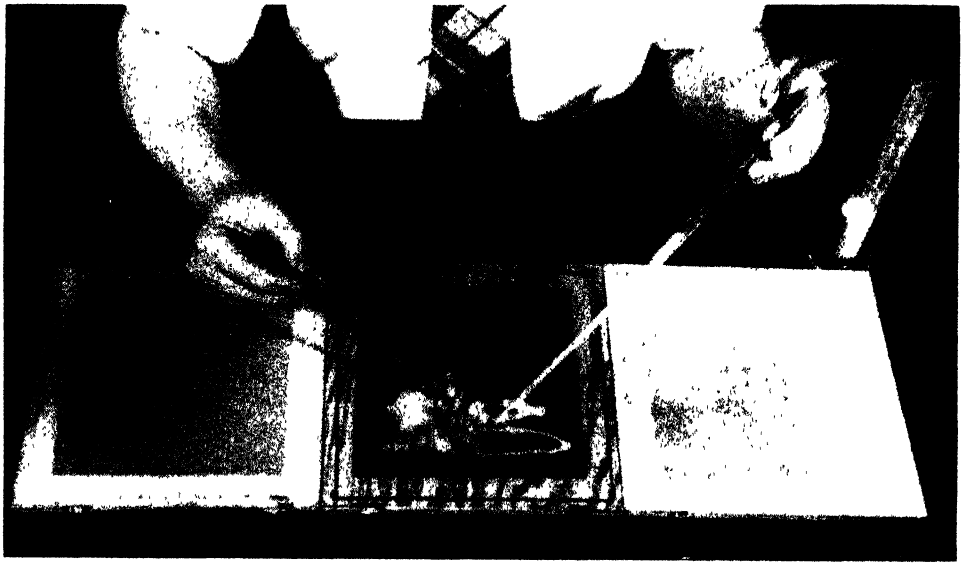

Fig. 4.—Three glass panels similar to those used in experiment. Left, panel with insecticide applied in settling spray tower; center, panel with insecticide being applied by means of brush and pipette; right, panel with insecticide already applied by means of brush and pipette.

Table 1 clearly reveals the correlation between the length of exposure and the percentage of mortality and knockdown resulting from each of the five principal chlorinated hydrocarbons used. The surface toxicity as indicated by the exposure needed to effect mortality made DDT and gamma hexachlorocyclohexane appear to be the most toxic, with chlordan, *Rhothane D-3*, and *Toxaphene* following in order.

Monro, Beaulieu, & Delisle (1947) reported no difference in mortality among lots of flies exposed for 10, 20, 30, 40, and 50 minutes to DDT deposits. Their reported results are at variance with data obtained from the experiment described here. Table 1 exhibits clearly the relationship of exposure time to mortality. Perhaps Monro and his co-workers used surfaces on which only a small amount of DDT was available to the flies, and in the first few minutes of exposure the flies rapidly eroded or removed the DDT available. In speed of knockdown, gamma hexachlorocyclohexane was the material ranking first; it was followed in order by DDT, *Rhothane D-3*, chlordan, and *Toxaphene*. Fifty per cent knockdown of house flies when exposed to *Toxaphene* was reported by Block (1948*b*) to require in some instances only 12 minutes, a period that represents a much faster knockdown rate than the 4 to 6 hours for complete knockdown reported by Beacher & Parker (1948). Data in table 1 indicate that about 167 minutes of exposure to *Toxaphene* is needed to give 50 per cent knockdown and 253 minutes for 99 per cent knockdown. It was noticed in the experiment reported here that there was no correlation between time required for knockdown and time required for kill. *Rhothane D-3*, which possessed much less surface toxicity than chlordan, actually gave quicker knockdown. Surface toxicity depends upon the availability of the insecticide as well as the actual toxicity.

Fig. 5.—Settling spray tower. Insecticide is introduced by a pipette into the atomizer at top of settling spray tower. A panel is placed on a sliding shelf in the bottom of tower. At 12.5 pounds air pressure, and after 3 minutes are allowed for settling, the dosage per square foot of panel is approximately 32.4 per cent of the quantity placed in the atomizer.

Table 1.—Effect of exposure time on mortality of house flies and time required for various knockdowns of flies by five chlorinated hydrocarbons when applied as suspensions to glass.

Water-Wettable Insecticide	Mg. Toxicant per Square Foot	Per Cent Mortality 24 Hours After Exposure Time of								Minutes Required for Knockdown of			
		5″*	15″	56″	3′45″	7.5′†	15′	60′	240′	10%	50%	90%	99%
50% DDT	50 mg.	5.2	57.2	81.2	96.3	99.3	97.8	100.0	100.0	20	32	45	50
		12.4	64.5	75.4	90.1	100.0	100.0	100.0	100.0	29	35	46	51
		8.0	42.8	84.7	87.6	97.2	100.0	100.0	100.0	22	34	45	60
Mean		8.5	54.8	80.4	91.3	98.8	99.3	100.0	100.0	24	34	45	54
50% Chlordan	50 mg.	—	2.8	11.1	47.5	74.7	96.5	100.0	100.0	61	80	100	122
		—	5.0	16.4	53.9	82.6	98.9	99.2	100.0	64	84	110	160
		—	3.2	12.1	40.7	66.0	94.7	100.0	100.0	68	85	113	153
Mean		-	3.7	13.2	47.4	74.4	96.7	99.7	100.0	64	83	108	145
5.2% Gamma hexachloro-cyclohexane	50 mg.	—	12.6	36.9	79.7	67.6	84.4	100.0	100.0	13	17	33	43
		—	7.0	45.1	52.7	91.4	100.0	100.0	100.0	17	20	38	48
		—	19.8	35.8	67.3	83.7	100.0	100.0	100.0	15	29	45	51
Mean		—	13.1	39.3	66.6	80.9	94.8	100.0	100.0	15	22	39	47
25% *Toxaphene*	50 mg.	—	—	9.7	16.6	—	31.8	69.7	98.2	100	165	195	240
			—	3.8	12.1	-	28.4	72.5	95.0	120	160	197	257
		—	-	10.2	18.3	—	34.1	65.3	99.1	117	175	205	262
Mean				7.9	15.7		31.4	69.2	97.4	112	167	199	253
50% *Rhothane D-3*	50 mg.	--	-	1.7	2.0	-	20.0	79.5	100.0	40	57	80	100
			--	0.0	6.5	—	24.7	84.1	99.1	40	55	90	120
		-		0.9	3.9	--	17.8	87.1	100.0	47	58	84	114
Mean				0.9	4.1	--	20.8	83.6	99.7	42	57	85	111

* ″ = seconds. † ′ = minutes.

In table 1 are indicated the proper exposure periods to be used in the experiments on residual toxicities, as follows: DDT and gamma isomer of hexachlorocyclohexane, 15 minutes; chlordan, 1 hour; and *Rhothane D-3* and *Toxaphene,* 2 hours. Exposures to deposits of 50 mg. toxicant per square foot for the periods indicated produced nearly 100 per cent mortality for each material.

Experiment 2: *Effect of Deposits on Mortality.*

—With what appears to be the best residual material (DDT) a study was conducted to establish if possible the influence of the amount of deposit on mortality of flies exposed 15 minutes. A series of glass plates were treated with a 50 per cent DDT water-wettable powder in a calculated range of 0.1875 mg. to 200 mg. (equivalent to 2,152 mg. per square

Table 2.—Mortalities of house flies exposed 15 minutes to various DDT suspension deposits on glass.

Deposit as Mg. of DDT per Square Foot of Glass	Per Cent Mortality 24 Hours After Treatment			Mean
	Replicate 1	Replicate 2	Replicate 3	
200.0	100.0	99.0	100.0	99.7
50.0	100.0	98.1	100.0	99.3
25.0	81.6	100.0	100.0	93.8
12.5	89.8	100.0	94.3	94.7
6.25	75.0	85.5	100.0	86.8
3.125	55.3	46.1	88.7	63.4
1.50	25.0	28.1	37.8	30.3
0.75	19.0	18.8	12.4	16.7
0.375	0.0	5.7	0.0	1.9
0.1875	0.0	3.1	0.0	1.0
0.0	0.0	2.1	0.0	0.7

NOTE: A 50 per cent DDT water-wettable powder was used to secure the DDT deposits.

Table 3.—Mortality of house flies exposed to surfaces sprayed with DDT at different dosages and degrees of coverage.

Mg. of DDT per Square Foot	Per Cent of Surface Sprayed	Per Cent Mortality 24 Hours After Exposure of				
		3 Seconds	15 Seconds	1 Minute	4 Minutes	16 Minutes
50	100	24 7	88 5	99 1	99 8	100 0
100	25	5 5	15 0	75 8	100 0	99 7
25	100	19 2	86 0	96 5	99 0	100 0
10	100	10 4	25 0	82 5	94 8	99 1

meter) DDT per square foot. Table 2 shows that a rather sharp drop in mortality did not occur until the deposit was 6.25 mg. per square foot or below. In this experiment, 25 mg. of DDT per square foot was nearly as effective as a 200 mg. deposit; calculations were based on the 24-hour mortality resulting from a 15-minute exposure. There was evidence of mortality occurring from a deposit as low as 0.375 mg. of DDT per square foot. A dosage of 50 mg. of toxicant per square foot was selected as high enough for obtaining critical information on persistence of deposits in succeeding tests. The writer felt that for critical residual studies excessive deposits might obscure differences in persistence.

Experiment 3: ***Relationship Between Coverage and Deposit.***—*Deenate* water-wettable powder mixtures at various dosages were sprayed in a settling spray tower upon glass plates in such a way as to obtain various degrees of coverage, as indicated in table 3. A 25 mg. per square foot deposit over 100 per cent of the surface was much more effective than a 100 mg. per square foot deposit over only 25 per cent of the surface. A deposit of 100 mg. of DDT on 25 per cent of the surface was no more effective than a 10 mg. deposit over the entire surface (about 0.4 as much actual DDT). Results show the greater importance of coverage and the lesser importance of dosage in effecting fly mortality.

No critical comparisons can be made between data obtained in this experiment and data on coverage obtained by Turner & Woodruff (1948), as in the Turner & Woodruff report comparable specific information is lacking on techniques of study, dosages, exposure times, numbers of flies used, and effect of flies on deposits.

Table 4.—Mortality of house flies exposed to surfaces sprayed for different degrees of coverage with 50 mg. DDT deposits per square foot.

Per Cent of Surface Sprayed	Per Cent Mortality 24 Hours After 4-Minute Exposure
10	12 5
20	64 0
30	91 1
40	99 0
50	99 6
100	100 0

Experiment 4: ***Coverage of Surface and Fly Mortality.***—As indicated in table 4, six panels were sprayed, with 10, 20, 30, 40, 50, and 100 per cent, respectively, of their surfaces covered with 50 mg. of DDT per square foot in the form of a water mixture of *Deenate* water-wettable powder.

On panels on which less than 30 per cent of the surface was treated, fly mortality resulting from a 4-minute exposure was low. Probably the fly does not have sufficient time to pick up a lethal dose of DDT in a 4-minute period of contact with a surface less than 30 per cent of which is treated.

Table 4 shows, in the random distribution of flies within a confined space, the desirability of extensive treatment, or as nearly complete a coverage as possible.

Table 3 indicates that a given amount of material is most effective when distributed over the whole surface. Therefore, in practical application, if a certain amount of material is to be used upon premises, it is advisable to cover all surfaces rather than to employ spot treatments, provided, however, that such an entire-coverage treatment does not con-

Table 5.—Mortality of house flies exposed to surfaces sprayed with DDT distributed heterogeneously and also homogeneously.

Formulation	Mg. DDT per Square Foot	Average Mg. DDT per Square Foot	Surface	Per Cent Mortality 24 Hours After Exposure of 15 Seconds	Per Cent Mortality 24 Hours After Exposure of 4 Minutes
No. 9 oil solution	20 200	110	Wood	96 0	100 00
No. 9 oil solution	110	110	Wood	93 2	100 00
No. 9 oil solution	50	50	Wood	87 0	99 08
Deenate water-wettable DDT powder in water	25-75	50	Glass	89 6	99 10
Deenate water-wettable DDT powder in water	50	50	Glass	88 1	99 40

taminate food or otherwise present a health hazard.

Experiment 5: ***Effect of Heterogeneous Deposits Upon Flies.***—The effect upon flies of uneven deposits of insecticides was determined through a series of tests in which materials were sprayed on surfaces in alternating bands of heavy and light deposits. DDT, 3.2 per cent, in no. 9 oil was sprayed in 10 alternating bands of 20 and 200 mg. per square foot upon a wood surface, and the resulting mortality in flies exposed to this surface was compared with resulting mortalities in flies exposed to one 110 mg. and one 50 mg. treatment. There was, of course, a certain amount of run-together of the bands (estimated at about 25 per cent) so that the crystalline deposit appeared wavelike, or as a truly uneven deposit. There was no significant difference in fly mortality resulting from exposure to the 20–200 mg. deposit and the deposits of 110 and 50 mg. No significant differences in fly mortality resulted when *Deenate* water-wettable DDT was applied to glass in four strips of 25 and 75 mg. per square foot and in a uniform deposit of 50 mg., table 5.

The tests described above lead to the

Table 6.—House fly knockdown and mortality resulting from 15-minute exposures to surfaces treated with several formulations at a dosage of 50 mg. DDT per square foot.

Per Cent DDT in Water-Wettable Powder	Source of Toxicant	Surface	Minutes Required to Obtain Knockdown of 1%	50%	99%	Mortality 25 Hours After a 15-Minute Exposure
50 0	Rohm & Haas 50% water-wettable powder	Glass	20	33	57	100 0
25 0	Rohm & Haas 50% water-wettable powder	Glass	22	36	58	99 2
10 0	Rohm & Haas 50% water-wettable powder	Glass	29	49	145	89 1
5 0	Rohm & Haas 50% water-wettable powder	Glass	38	72	290	49 9
2.0	Rohm & Haas 50% water-wettable powder	Glass	50	140	540	14 0
0 5	Rohm & Haas 50% water-wettable powder	Glass	360	1,080	2,880	1 3
5 0	*Deenate* 50% water-wettable powder	Glass	35	58	315	46 2
5 0	*Deenate* 50% water-wettable powder	Wood	40	60	340	37 4
5 0	*Deenate* 25% emulsifiable concentrate	Glass	55	215	1,290	10 1
5.0	*Deenate* 25% emulsifiable concentrate	Wood	25	35	58	95.3

conclusion that perfectly uniform deposits may not be necessary or even advantageous on surfaces on which residual toxicant deposits are excessive. This conclusion confirms results of experiments in which there was no apparent difference in mortality rates resulting from deposits obtained by spraying and those obtained by painting. The painted deposits were obviously not perfectly uniform, fig. 4.

Experiment 6: ***Wall Coats Containing DDT.***—When many so-called wall coats containing DDT appeared upon the market, laboratory tests were progressing upon amounts of DDT in the suspension-type wall coats needed to produce the necessary lethal action. In addition, a means was being sought whereby a good wall coat might be produced. Formulations containing 0.5, 2.0, 5.0, 10.0, and 25.0 per cent DDT were prepared from Rohm & Haas wettable DDT powder and sprayed upon glass panels at the rate of 50 mg. actual DDT per square foot. The treated panels were permitted to dry and age 4 weeks before being tested.

The data in table 6 make it evident that mortality and knockdown were not changed until the concentration of DDT was reduced to 10 per cent or less. The writer is doubtful if any wall coat containing as little as 2 to 5 per cent DDT could compete in fly control with 50 per cent DDT water-wettable powder in field operations. In the 50 per cent water-wettable powder, approximately half of the surface particles are actual DDT, whereas in the wall coat probably 2 to 5 of 100 surface particles are actual DDT.

A few experiments with laboratory wall-coat formulations, in which 25 per cent DDT emulsifiable concentrate was reduced to 5 per cent DDT by mixture with *Cherokee* clay and used in place of the water-wettable powder, proved quite satisfactory. When this formulation was sprayed upon wood or other porous surfaces a highly toxic bloom occurred usually within a week. When applied to glass, the DDT "bloomed-in" and crystallized upon the glass beneath. Used commercially, such a formulation would probably not be sprayed upon glass or other highly polished surfaces and would likely surpass most wall coats being used in controlling flies.

Block (1948*a*) mentions a number of good references to research on insecticidal surface coatings. Also, he offers valuable information about such coatings, in which the toxicant appears to be retained longer than might ordinarily be expected. Most of Block's work was with coatings containing 20 per cent DDT, and his data are recorded in number of minutes required to give 50 per cent knockdown.

Experiment 7: ***Effect of Successive Exposures on Persistence of Toxic Residue.***—What wearing effect do numerous flies have upon a deposit of residual insecticide? Ten cages of flies were exposed for successive periods of 15 minutes each to each of the DDT-treated surfaces listed in table 7, and 24-hour mortality data were recorded.

Results of tests, designed to test fly erosion of DDT residues, indicate not only tenacity of deposits but also a stimulating seeding effect of flies when exposed to surfaces that are just beginning to bloom. On such surfaces it is evident that there exists a layer of blobs of supersaturated solvents that respond to various stimuli and bloom out in a dense mat of very fine crystals. These stimulated blooms (crystallization on the surface) are, according to the erosion test, very resistant to wear.

Examining the data by solvents and surfaces reveals some very interesting trends. *PD 544-C* emulsions, when applied to wood, form not only a good initial bloom but also a very dense secondary seeded mat of crystals, all of which resist wear. On glass the *PD 544-C* formulation maintains a rather low order of toxicity, with no apparent loss by fly erosion. Microscopic examination of deposits of DDT from the slower-drying solvents shows that the large crystals for the most part lie flat upon the glass surface, figs. 6, 9, and 10. The position of the crystals probably explains their low degree of toxicity and their long wear. A mixture of water-wettable powder that has been sprayed on glass erodes to some degree as evidenced by both biological and visual observations. Erosion of the residue is greatly retarded by the addition of 5 per cent bone glue by weight to the 50 per cent DDT water-wettable powder. The *Deenate* water-wettable powder appears to erode more

Table 7.—Influence of surfaces, solvents, formulations, method of application, and fly activity upon toxicity and maintenance of residual effectiveness of DDT deposits.

Panel No.	Solvent or Formulation	Method of Application	Age of Deposit in Days	Crystals	Surface	Per Cent Mortality 24 Hours After Stated Exposure of Flies to the Surface									
						1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
1	*PD 544-C**	Painted	6	Medium fine	Wood	100.0	100.0	100.0	100.0	92.0	90.0	87.0	99.0	98.0	83.0
2	*PD 544-C**	Painted	6	Medium fine	Wood	100.0	97.0	100.0	100.0	88.0	100.0	90.0	87.0	96.0	100.0
3	*PD 544-C**	Painted	6	Large	Glass	16.0	37.0	17.0	28.0	26.0	21.0	18.0	23.0	28.0	21.0
4	*PD 544-C**	Painted	6	Large	Glass	12.0	15.0	15.0	22.0	19.0	33.0	22.4	22.0	14.0	23.0
5	*PD 544-C**	Painted	6	Large	Glass	41.0	26.0	45.0	26.0	68.0	42.0	50.0	50.0	41.0	49.0
6	Laboratory water-wettable powder	Painted	6	—	Glass	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
7	*Deenate* water-wettable powder	Painted	6	—	Glass	100.0	100.0	100.0	100.0	100.0	100.0	97.3	98.2	98.5	76.7
8	*Deenate* water-wettable powder	Sprayed	6	—	Glass	100.0	100.0	100.0	100.0	96.5	100.0	100.0	99.2	64.2	83.0
9	*Deenate* water-wettable powder and glue	Sprayed	6	—	Glass	100.0	100.0	97.7	100.0	92.0	99.2	95.0	100.0	100.0	100.0
0	Controls	—	—	—	Glass	1.0	0.0	2.1	1.9	0.0	0.0	0.0	3.2	1.8	0.0
10	Ethyl alcohol	Sprayed	6	Superfine	Glass	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
11	Ethyl alcohol	Painted	6	Superfine	Glass	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
12	*HB-40*†	Sprayed	6	Oily surface, none	Wood	36.4	27.3	41.5	32.7	26.7	28.6	25.2	26.7	43.0	16.8
12	*HB-40*†	Sprayed	11	None	Wood	0.0	2.6	0.0	0.0	0.0	0.0	0.0	2.4	0.8	0.9
12	*HB-40*†	Sprayed	18	Large	Wood	34.2	10.7	3.0	8.1	7.0	—	—	—	—	—
12	*HB-40*†	Sprayed	30	Large	Wood	80.0	—	—	—	—	—	—	—	—	—
13	Xylene†	Sprayed	6	Medium fine	Wood	100.0	88.7	65.7	44.5	37.5	34.8	39.6	48.0	43.2	42.0
13	Xylene†	Sprayed	11	Medium fine	Wood	100.0	68.7	54.4	24.2	13.6	6.8	4.2	4.6	12.6	17.2
13	Xylene†	Sprayed	18	Medium fine	Wood	13.1	14.8	4.0	1.8	1.0	—	—	—	—	—
13	Xylene†	Sprayed	30	Medium fine	Wood	7.9	—	—	—	—	—	—	—	—	—
14	*Velsicol AR-60*†	Sprayed	6	Oily surface, few medium	Wood	35.3	36.8	35.6	18.8	50.0	39.8	52.5	27.9	15.0	18.2
14	*Velsicol AR-60*†	Sprayed	11	Medium	Wood	100.0	99.2	88.0	98.4	64.6	34.5	52.0	92.3	38.4	79.0
14	*Velsicol AR-60*†	Sprayed	18	Medium	Wood	25.5	9.2	10.7	6.7	25.3	—	—	—	—	—
14	*Velsicol AR-60*†	Sprayed	30	Medium	Wood	16.0	—	—	—	—	—	—	—	—	—
15	Xylene + ethylene dichloride†	Sprayed	4	Medium fine	Wood	80.8	91.3	62.3	85.1	86.3	74.2	23.0	54.1	56.8	35.7

*2% *B-1956* + 3% *Triton X-155* emulsifiers.
†5% *Atlox 1045-A* emulsifier.

Table 7 (continued)

Panel No.	Solvent or Formulation	Method of Application	Age of Deposit in Days	Crystals	Surface	Per Cent Mortality 24 Hours After Stated Exposure of Flies to the Surface: 1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
15	Xylene + ethylene dichloride†	Sprayed	15	Very fine and matted	Wood	100.0	99.1	100.0	100.0	100.0	88.7	85.8	91.2	94.9	99.2
16	Xylene + carbon tetrachloride†	Sprayed	4	Medium fine	Wood	100.0	100.0	99.3	71.2	75.2	46.8	27.8	66.2	31.4	24.1
16	Xylene + carbon tetrachloride†	Sprayed	15	Very fine and matted	Wood	100.0	100.0	100.0	99.1	95.3	99.2	100.0	100.0	100.0	100.0
17	Xylene†	Sprayed	2	Medium fine	Wood	100.0	100.0	95.7	86.4	63.0	31.2	20.0	28.4	37.8	44.4
17	Xylene†	Sprayed	15	Fine and matted	Wood	100.0	100.0	100.0	99.1	95.3	100.0	86.4	88.0	74.2	85.3
18	Xylene†	Sprayed	3	Medium fine	Wood	100.0	100.0	88.6	64.4	25.4	13.6	6.4	58.2	6.7	14.9
18	Xylene†	Sprayed	15	Medium fine	Wood	100.0	96.1	80.0	51.1	12.2	9.1	13.2	14.3	11.0	10.1
19	Xylene†	Sprayed	30	Medium fine	Wood	100.0	100.0	96.0	93.2	77.7	78.7	48.5	69.0	71.5	75.2
20	*PD 544-C**	Sprayed	6	Medium fine	Wood	100.0	100.0	99.2	97.3	85.7	97.2	100.0	81.0	88.2	91.0
20	*PD 544-C**	Sprayed	11	Very fine and matted	Wood	100.0	100.0	100.0	100.0	100.0	100.0	99.3	100.0	100.0	100.0
21	*PD 544-C**	Sprayed	6	Medium fine	Wood	100.0	100.0	100.0	96.1	100.0	100.0	97.1	79.2	84.3	88.3
21	*PD 544-C**	Sprayed	11	Very fine and matted	Wood	100.0	100.0	99.3	100.0	100.0	100.0	100.0	100.0	99.1	100.0
22	Xylene‡	Painted	2	Surface appearing wet; few medium fine	Glass	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
22	Xylene‡	Painted	15	Fine and very fine	Glass	100.0	100.0	100.0	100.0	100.0	100.0	99.8	97.4	100.0	94.8

* 2% *B-1956* + 3% *Triton X-155* emulsifiers.
† 5% *Atlox 1045-A* emulsifier.
‡ 10% *Triton X-100* emulsifier.

rapidly than the laboratory water-wettable powder formulation in which *Cherokee* clay is used as a diluent.

The three formulations in which *HB-40*, xylene, and *Velsicol AR-60* were solvents, and *Atlox 1045-A* was used as the emulsifier, had different degrees of bloom and wear. The first test period 6 days after treatment showed considerable degradation of the well-crystallized DDT-xylene deposit; in the other two formulations, little loss of toxicity was noted from the first through the tenth exposure. Examination under a microscope revealed no crystals present where *HB-40* had been used and very few where *Velsicol AR-60* was employed. Five days later, when these same surfaces were again tested in like manner, the xylene treatment had eroded severely, that containing *AR-60* had eroded slightly, and the *HB-40* treatment showed no toxicity and no bloom. The *HB-40* treatment then appeared dry, whereas in the first series of tests it had a wet appearance. A third test of only five series of exposures on the eighteenth day and examination of deposits proved the appearance of crystals upon the surface of the *HB-40* treatment. The xylene treatment indicated a continued slow, inconspicuous bloom, and the *AR-60* treatment a more noticeable bloom. By the time of the last test, on the thirtieth day, of but one cage of flies, the results suggested that the rate of bloom is directly proportional to the rate of volatilization of the solvent. Thus, in 30 days *HB-40* had only begun to permit the crystallization of DDT; xylene had apparently passed its peak of crystallization by the fifth day, and *Velsicol AR-60* by the eleventh day. Probably some of the DDT remains bound in the wood as a supersaturated or saturated solution in any of these solvents for periods much longer than those indicated here.

Further studies with xylene as a solvent, as indicated in table 7, lead to the belief that, if the desirable secondary bloom is to be obtained, the flies, or whatever device is used for seeding the surface, should be on the surface not later than the second day. Thus, the period of seeding a xylene treatment seems somewhat limited. If, however, we add to the xylene emulsion-concentrate about 20 per cent ethylene dichloride or carbon tetrachloride we find that a deposit bearing DDT will react to the stimulus on the fourth day to produce a plainly visible heavy white crystalline mat of extremely small, fine crystals on the wood surface. Of all the seeded blooms, these and the ones produced by the *PD 544-C* treatments were the heaviest and most resistant to wear at a high level of toxicity. Of all the formulations except those made with water-wettable powders, the 1.62 per cent DDT solution in 95 per cent ethyl alcohol produced the most lethal and tenacious deposits on glass surfaces when either sprayed or brushed upon the surfaces. It produced the finest crystalline deposits, and its crystallization was the most rapid, fig. 8.

Microscopic study of all solution deposits on glass revealed that rarely was crystallization complete. Usually a few or many minute blobs of supersaturated solution persisted among the DDT crystals, fig. 12. On glass and, less noticeably, on wood the size of the DDT crystals was determined by the speed of crystallization, which, in turn, was determined by the physical properties of the solvent, figs. 6–13; rapid crystallization produced crystals of minute size. This phenomenon was especially noticeable where surface treatments were seeded by fly activity at the proper time and crystallization was at once initiated at the innumerable sites of fly contact. Often it was noted that dust, dirt, and scratches stimulated the formation of crystals on glass, fig. 13.

Schmitz & Goette (1948) apparently showed the degree of penetration of DDT solutions into poplar wood. The opinion of the present writer is that the degree of penetration may be influenced by highly variable elements in the environment. For example, under a certain set of conditions it is possible that most of the DDT could be crystallized on the surface of the wood if the solvent is highly supersaturated when the surface is stimulated. Without the stimulation, much of the DDT could remain dissolved and held in the wood by the solvent. Certain components of wood have shown a visible influence upon the bloom; it has been observed that frequently bloom occurs on the soft part of the wood between the hard or resinous annual rings before a crystalline formation occurs on the annual rings. On certain pieces of

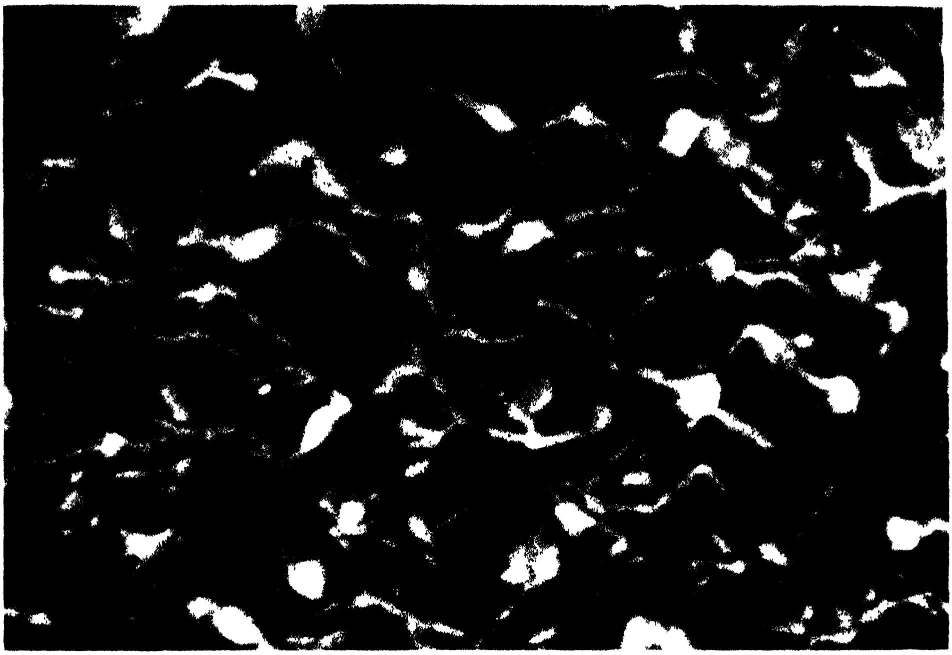

Fig. 6.—DDT crystallization from *PD 544-C* emulsion. ×40. Crystals of DDT formed from solvents that evaporate slowly tend to be large, lie flat on the glass, and exhibit low toxicity and high resistance to erosion.

Fig. 7.—DDT crystallization from no. 9 oil on glass. ×40. The large crystals are plainly visible to the unaided eye.

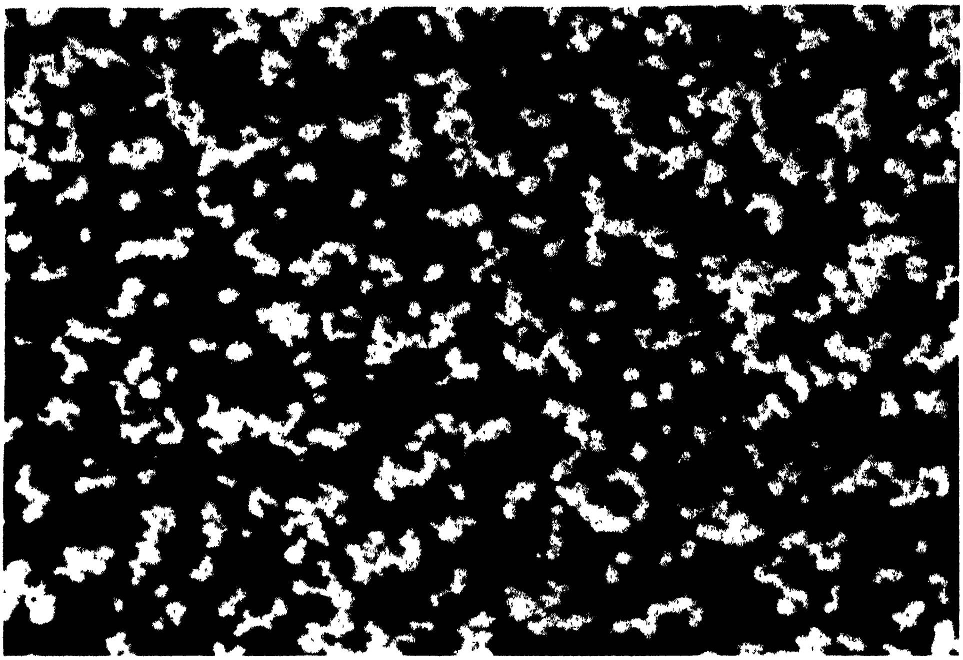

Fig. 8.—DDT crystallization from ethyl alcohol solution on glass. × 40. The minute crystals, not visible individually but only as dense hemispherical masses, have high toxicity and are resistant to erosion.

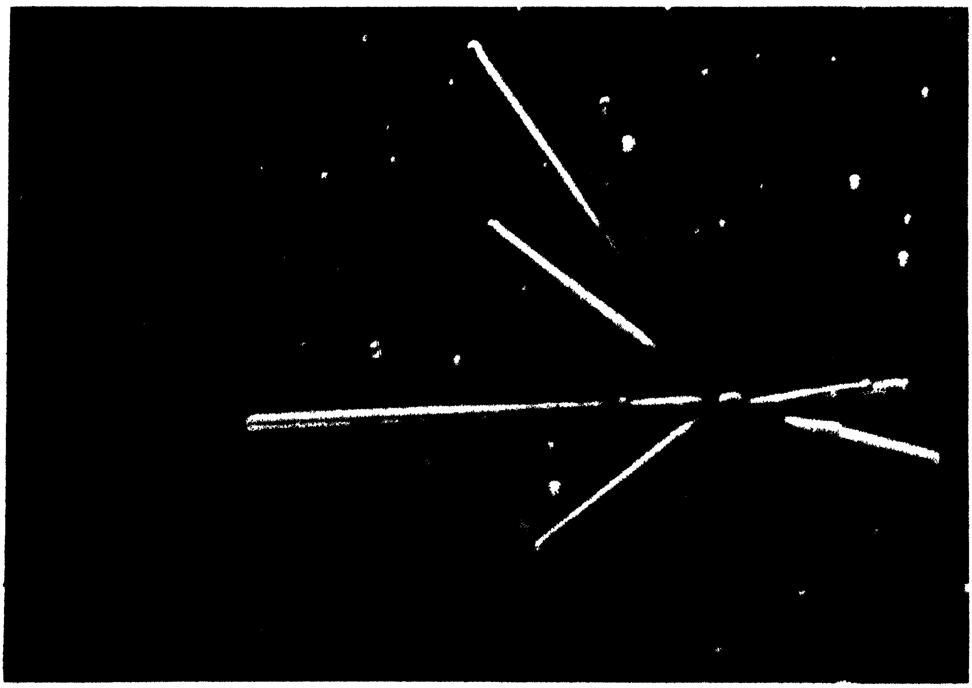

Fig. 9.—DDT in process of crystallizing from an *HB-40* solution. × 40. The very large crystals, which lie flat upon the glass, are characteristic of very slow crystallization.

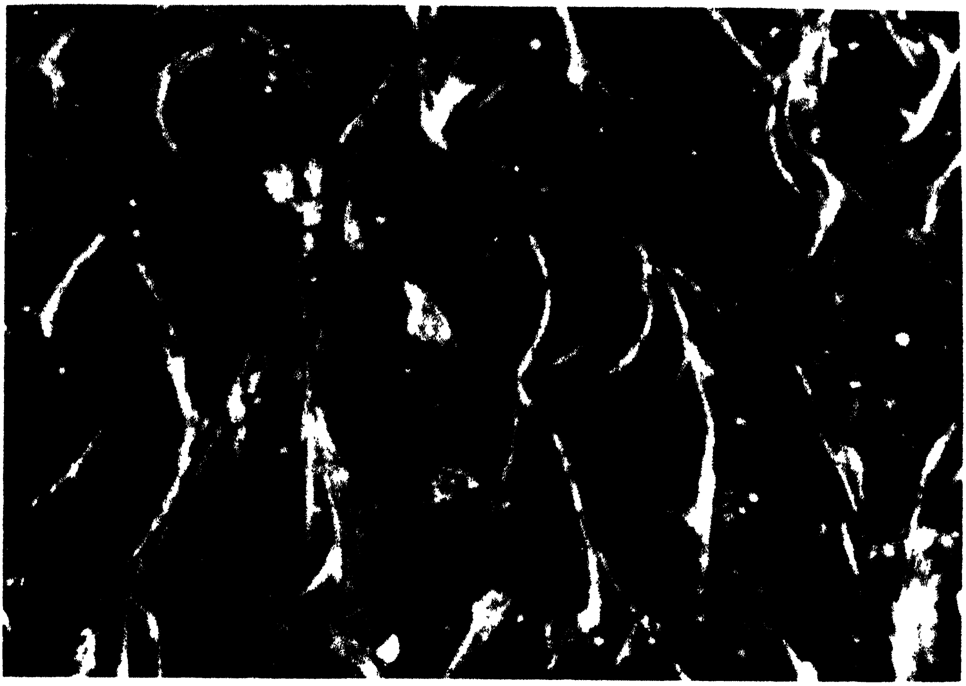

Fig. 10.—DDT crystallization from a *Velsicol AR-60* emulsion. ×40. The crystals lying flat and forming a network on glass, have low toxicity and are resistant to erosion.

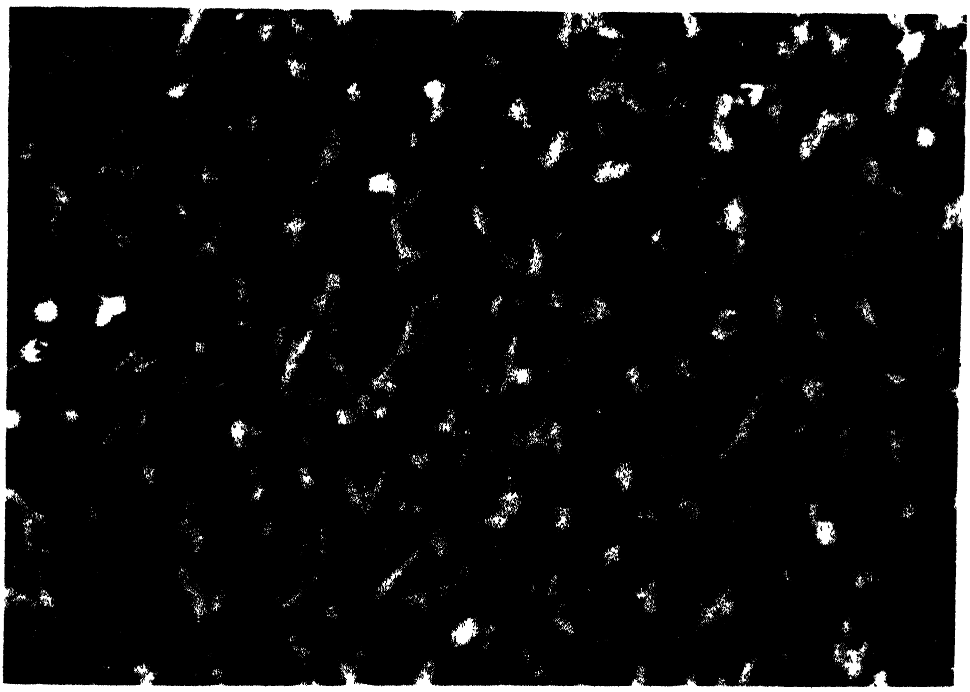

Fig. 11.—DDT crystallized from xylene emulsion on glass. ×40. Network of crystals similar to that from *Velsicol AR-60,* but the individual crystals are smaller.

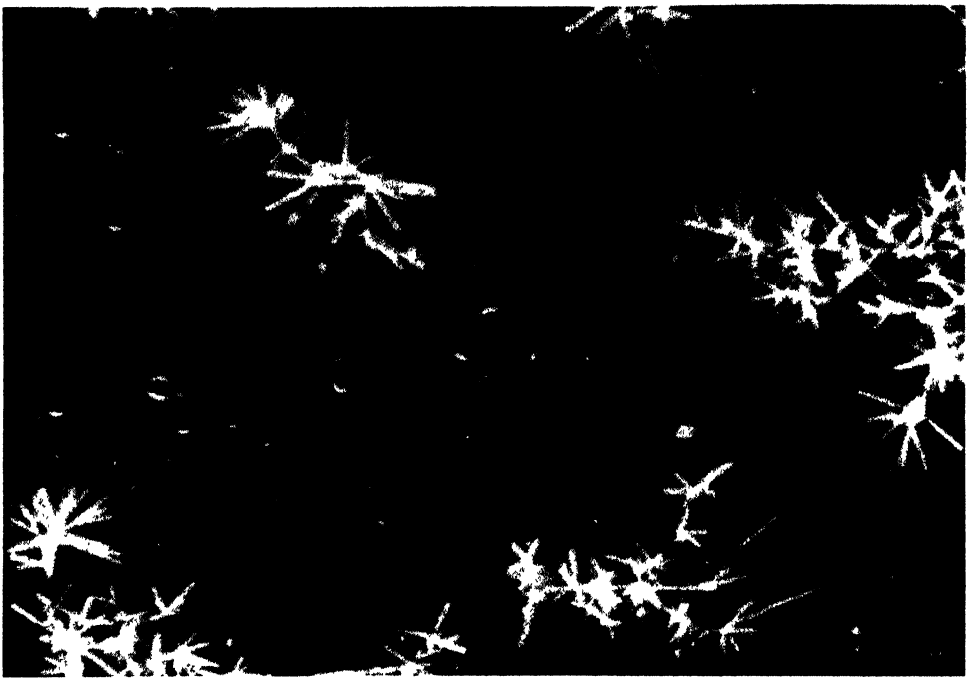

Fig. 12.—DDT in process of crystallizing from xylene solution on glass. ×40. The xylene droplets (center of picture) among the crystals are susceptible to seeding by dust or flies.

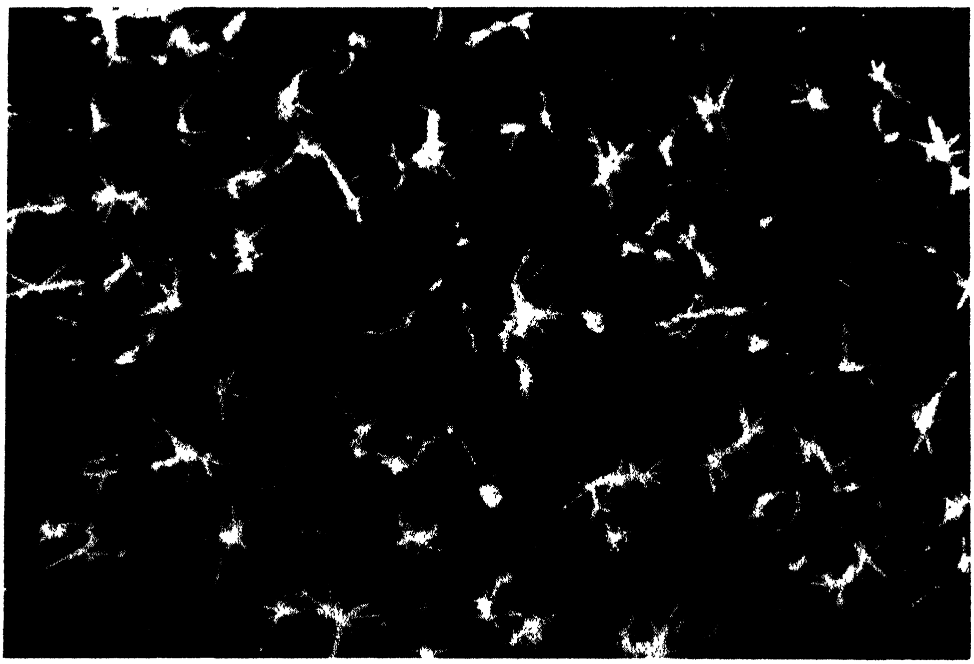

Fig. 13.—DDT in process of crystallizing from xylene solution. ×40. The solution on the glass shown here was seeded by dust, and crystallization started sooner than on glass shown in fig. 12.

wood, when a bloom occurs on the soft part of the wood, it does not occur on the annual rings. Thus, it seems that penetration or retention of DDT in the wood depends upon the physical properties of the solvent and the particular piece of wood used, in addition to environmental elements.

Experiment 8: ***Fumigation Properties.***—During the course of the studies, difficulty was encountered with contamination of air in the room containing the fly-stock cage. Investigation of this situation revealed that the only possible source of contamination was chlordan-treated surfaces at the opposite end of the room. Preliminary tests indicated that *Toxaphene*, *Rhothane D-3*, and DDT did not act as fumigants to any noticeable extent; on the other hand, chlordan and gamma hexachlorocyclohexane seemed very toxic as fumigants.

A study was made of the fumigation action of chlordan and gamma hexachlorocyclohexane. Caged flies were placed in a large battery jar (11.6 liters capacity) with 18 square inches of treated surface. The top of the jar was sealed with a glass plate smeared with a glycerine-betonite jell. Exposure times of six groups of flies to the air in the jars were, respectively, 15, 30, 60, 120, 240, and 480 minutes. The results of four replicates are shown in table 8. The losses of weight from the treated surfaces were used to calculate the dosage as milligrams per 1,000 cubic feet or 28.365 cubic meters. One mg. per 1,000 cubic feet is equivalent to 0.0353 mg. per cubic meter. It was difficult to believe that the calculated dosages actually existed as a vapor, but rather existed as condensations or adsorptions over the entire inside surface of each jar. It seemed conceivable that there was a transfer of the toxicant to the lipoid material in the insect's body and consequently that a lethal concentration of the toxicants accumulated. These data indicate the high order of toxicity to house flies of vapors that were given off from chlordan and hexachlorocyclohexane. Chlordan and hexachlorocyclohexane were compared with HCN, one of the most toxic fumigants, and found to be approximately 62 and 206 times as toxic, respectively. Fly fumigation data

Table 8.—Mortality of house flies 24 hours after exposures of various periods to vapors of chlordan and hexachlorocyclohexane residues.

TOXICANT	PER CENT MORTALITY 24 HOURS AFTER EXPOSURE OF					
	15 '*	30 '	60 '	120 '	240 '	480 '
Chlordan	2.6	30.0	58.0	68.5	82.8	98.1
Chlordan	1.0	4.9	24.5	91.8	99.2	100.0
Chlordan	1.9	20.9	63.7	83.2	100.0	100.0
Chlordan	0.9	6.3	24.1	81.4	97.0	100.0
Mean	1.6	15.5	42.8	81.2	94.8	99.5
Average dosage calculated as mg. per 1000 cubic feet	1.51	3.04	6.07	12.14	24.28	48.56
Gamma isomer of hexachlorocyclohexane.	1.0	14.8	25.6	64.0	99.1	100.0
Same as above	1.9	6.1	25.0	71.4	95.2	100.0
Same as above	1.0	14.7	42.1	75.0	99.1	100.0
Same as above	0.0	4.1	20.0	54.1	88.2	99.2
Mean	1.0	9.9	28.2	66.1	95.4	99.8
Average dosage calculated as mg. per 1000 cubic feet	0.52	1.06	2.11	4.22	8.44	16.88
Check						0.0
Check						1.1
Check						0.0
Check						1.9
Mean						0.75

* = minutes.

by Eddy (1929) were used in the calculations. The use of chlordan or hexachlorocyclohexane as residual fumigants within confined spaces is suggested by results of this experiment.

Experiments 9 and 10: *Testing Periods*.—To limit the reduction of surface toxicity by fly erosion, the number of test periods in these experiments was held to a minimum.

Table 9.—Mortality of house flies 24 hours after exposure to various treated surfaces subjected to several combinations of environmental elements. Surfaces were tested 2, 22, and 182 days after treatment with commercial emulsions of residual insecticides.

Toxicant	Exposure	Surface	Mean Per Cent Mortality in Three Replicates: 2 Days After Treatment	22 Days After Treatment	182 Days After Treatment
DDT	South outside	Wood	99.70	11.90	0.00
	North outside	Wood	99.43	31.07	0.00
	North sheltered	Wood	99.07	46.53	8.07
	Inside	Wood	100.00	100.00	88.83
	South outside	Glass	46.23	100.00	3.83
	North outside	Glass	43.23	99.40	10.83
	North sheltered	Glass	42.83	56.97	19.53
	Inside	Glass	45.33	35.63	21.17
	South outside	Painted wood*	0.33	2.33	—
	Inside	Painted wood*	0.63	19.93	0.00
	South outside	*Cellutex*	97.80	9.90	—
	Inside	*Cellutex*	96.67	97.27	36.30
	South outside	Brick	74.97	6.33	
	Inside	Brick	71.87	38.33	11.87
	South outside	Concrete	0.97	0.00	
	Inside	Concrete	1.30	0.80	0.00
	South outside	Whitewash	2.30	4.07	—
	Inside	Whitewash	1.57	5.06	0.00
	South outside	Galvanized	57.73	8.47	—
	Inside	Galvanized	38.80	26.57	67.43
Chlordan	South outside	Wood	98.37	14.27	0.00
	North outside	Wood	98.17	7.93	0.00
	North sheltered	Wood	98.93	16.30	0.00
	Inside	Wood	98.77	14.17	0.00
	South outside	Glass	98.97	15.93	0.00
	North outside	Glass	99.10	22.70	0.37
	North sheltered	Glass	99.43	10.80	0.30
	Inside	Glass	97.33	43.30	0.00
	South outside	Painted wood*	69.13	2.92	—
	Inside	Painted wood*	68.30	3.93	0.60
	South outside	*Cellutex*	85.97	7.10	—
	Inside	*Cellutex*	88.70	17.41	0.30
	South outside	Brick	84.53	0.90	—
	Inside	Brick	83.35	3.17	—
	South outside	Concrete	64.60	2.37	—
	Inside	Concrete	56.50	4.23	
	South outside	Whitewash	67.07	3.00	—
	Inside	Whitewash	76.23	29.37	—
	South outside	Galvanized	94.67	25.53	—
	Inside	Galvanized	96.50	35.20	0.00
Rhothane D-3	South outside	Wood	66.33	10.43	0.00
	North outside	Wood	60.07	11.37	0.00
	North sheltered	Wood	59.43	27.60	6.63
	Inside	Wood	58.60	19.07	12.00
	South outside	Glass	58.23	13.27	0.00
	North outside	Glass	70.90	16.43	0.60
	North sheltered	Glass	73.57	40.40	7.60
	Inside	Glass	65.43	35.70	31.03

* Flat white wall paint containing vegetable oil vehicle.

Table 9 (continued)

Toxicant	Exposure	Surface	Mean Per Cent Mortality in Three Replicates		
			2 Days After Treatment	22 Days After Treatment	182 Days After Treatment
Gamma isomer of hexachloro-cyclohexane	South outside	Wood	94.23	0.70	0.00
	North outside	Wood	97.17	3.63	0.33
	North sheltered	Wood	97.53	1.00	0.00
	Inside	Wood	98.33	31.97	1.57
	South outside	Glass	99.13	0.43	—
	North outside	Glass	97.00	0.70	–
	North sheltered	Glass	98.66	9.23	0.27
	Inside	Glass	97.87	45.93	0.90
	South outside	Painted wood*	61.70	12.33	—
	Inside	Painted wood*	60.37	32.33	0.00
	South outside	*Cellutex*	72.63	3.60	—
	Inside	*Cellutex*	73.77	10.33	
	South outside	Brick	69.03	1.67	-
	Inside	Brick	90.67	5.20	—
	South outside	Concrete	50.03	0.00	–
	Inside	Concrete	43.97	0.90	–
	South outside	Whitewash	89.00	1.13	—
	Inside	Whitewash	86.90	9.30	
	South outside	Galvanized	99.80	11.90	3.20
	Inside	Galvanized	99.47	0.00	0.00
Toxaphene	South outside	Wood	70.33	4.43	—
	North outside	Wood	64.77	1.30	—
	North sheltered	Wood	71.60	44.67	0.00
	Inside	Wood	71.13	63.90	0.93
	South outside	Glass	99.37	22.47	0.00
	North outside	Glass	98.90	6.37	0.00
	North sheltered	Glass	98.53	62.10	3.80
	Inside	Glass	98.33	84.37	5.27
Control			1.17	0.67	0.63
			1.57	—	—
			1.47	—	—
			0.57	-	—
Mean difference necessary for significance, 0.05 level			9.11	25.54	4.95
Mean difference necessary for significance, 0.01 level			21.11	33.66	6.58

* Flat white wall paint containing vegetable oil vehicle

In experiment 9, only three test periods were used and in experiment 10 four test periods. If, at the end of 22 days in experiment 9, a material had lost its toxicity it was considered to be of little value as a residual insecticide in fly control on farms. If it proved to be toxic at the end of 22 days, it was considered for further testing at the 182-day test period. Any material that showed toxicity at the end of 182 days was regarded as very persistent and possessed of adequate residual kill properties for any practical application.

In experiment 10, 2-, 12-, 32-, and 152-day test periods were employed. Two- and 12-day periods were used to obtain data on panels coated with materials having a short residual life. The 32-day period was used to measure materials with a satisfactory period of toxicity for most structural pest control purposes, and the 152-day period was used to obtain information needed on those materials of truly long residual activity such as those desirable for fly control on farms or those presenting a residue problem on foodstuffs.

Experiment 9: ***Field Persistence of Residues From Commercial Emulsions.***—Five toxicants were applied

to eight surfaces—planed fir, glass, painted wood (1 month old), *Cellutex* (similar to *Celotex*), brick, concrete, whitewashed wood (1 month old), and galvanized iron —at a rate of 50 mg. per square foot, table 9. Treatments on wood and glass were exposed to various elements of the weather. Three replicates of each treatment on glass and wood were placed in situations on the South Farm of the University of Illinois so that one set was inside; another was outside on the south side of buildings exposed to all the elements; the third was on the north side of buildings; and the fourth was under a shelter that gave protection from sun and rain. The four positions may be described simply as the inside, the south exposure, the north exposure, and the sheltered. Surfaces other than glass and planed fir were placed in two positions—the south outside exposure and the inside. The objective of this experiment was to obtain information on the persistence of the five toxicants on the eight surfaces under various conditions. A study of table 9 will reveal the insecticides that were found to be most persistent under various conditions and also the surfaces on which insecticides were retained the greatest length of time.

Experiment 10: ***Field Persistence of Residues From a Standardized Formulation of Emulsions.***—The plan of this experiment was essentially the same as that of experiment 9. The variable of formulation was eliminated, and better-defined positions of exposure to the climatic elements were set up. Treated panels were exposed by means of suitable supports, fig. 14, on top of a flat-roofed

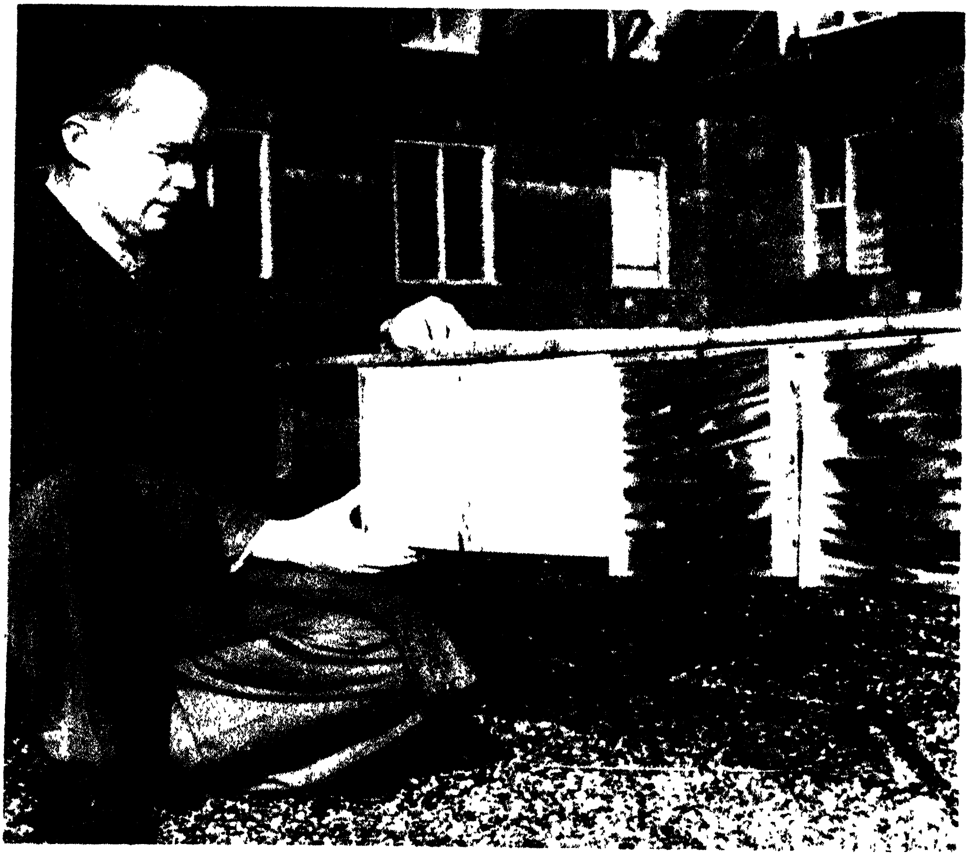

Fig. 14.—Securing treated panels to pipe rack for determining the effects of weathering upon toxicities of residues.

building. Some panels were secured to a pipe rack in north and south outside positions. Others were placed on racks beneath a shelter designed to keep out rain and sunshine. Still others were kept in the laboratory. The same solvent and emulsifying agent were used in all formulations. The emulsifiable concentrates contained 65 per cent xylene, 10 per cent *Triton X-100*, and 25 per cent by weight of the toxicant. These were diluted with water to give an emulsion containing 1 per cent of the insecticide. Incorporated with this experiment were tests with DDT water-wettable powder; it was hoped that such a formulation would overcome some of the surface hazards encountered with emulsions.

Experiments 9 and 10: *Discussion.* —Results of these tests are shown in tables 9 and 10. DDT was the outstanding residual insecticide. *Rhothane D-3* was the next most persistent material, with *Toxaphene* a good third choice. Gamma hexachlorocyclohexane and chlordan were the least persistent. Probably one of the greatest hazards was dust. Dust particles falling upon treated surfaces introduced a variant, not measureable. Nevertheless, dust presents one of the conditions frequently found under field conditions.

Analysis of these data made it evident that differentiation among elements is difficult. Rain appeared by visual evidence and biological assay to be the prime element in the degradation of the residual deposits. The deposits that were exposed to rain were more persistent on hard impervious surfaces (glass and galvanized iron) than on porous surfaces (brick, fir wood, and *Cellutex*). On painted wood, concrete, and whitewashed wood the initial and residual toxicity of the insecticides to house flies was lower than on other surfaces. The deposit from 50 per cent DDT water-wettable powder gave promising results on all surfaces. At the end of 152 days, the DDT suspension deposits were significantly toxic on all inside surface treatments except whitewashed wood.

The emulsion containing *PD 544-C* and DDT that was used to obtain data in table 9 shows the typical high toxicity of the initial tests on wood; considerable losses were incurred as a result of erosion and degradation by the twenty-second day of the test. Those panels with south exposure (exposed to all the elements) showed the greatest losses; those with north exposure (exposed to all elements except sunshine) showed approximately 20 per cent greater killing power. These losses may be accounted for by one or both of two possibilities: (1) direct sunlight or the heat produced by solar radiation; (2) rain driven onto the panels by a prevailing southwest wind. Wood panels sheltered from rain as well as sun exhibited about 15 per cent greater mortality to flies than the ones with north exposure. Wood panels placed within buildings retained their toxicity beyond the 22nd day and even to the 182nd day. The difference in toxicity between those wood panels held indoors and those in sheds where they were sheltered from external elements (sunshine and rain) might be assigned to one or both of two possibilities: wind erosion and dust accumulation found in the sheds.

The second series of tests (experiment 10) with uniform emulsions reveals no significant differences between those panels retained within the laboratory and those kept in a shelter constructed on top of a building. Both sites were relatively dust-free in contrast to the interior of the sheds used in the first test. In light of available information, it must be assumed that the real cause of degradation of the surfaces in the sheltered positions of the first series of tests (experiment 9) was dust accumulation and not wind erosion.

The glass panels treated with DDT emulsions may at first appear to offer somewhat contradictory evidence of toxicity unless the difference in solvents and emulsifiers used in the first and second series of tests is kept in mind.

In experiment 9, with a commercial *PD 544-C* emulsion of DDT on glass, the deposits and the test clearly showed that the rain, wind, or some other element found in the outside positions caused the DDT residue, a large part of which existed as a supersaturated solution in *PD 544-C* and emulsifier, to bloom or crystallize out. A microscopic comparison of the residues on the panels at the time of testing on the twelfth day revealed the presence of practically no supersaturated blobs

on the glass panels from the two outside positions in contrast to much supersaturated fluid on those inside, particularly those sheltered from all the elements, including the wind. By the 182nd day, however, the order of residual toxicity was reversed by the wear of the elements.

In tests with uniform emulsions (experiment 10) where xylene was the solvent, seeded crystallization occurred on glass earlier (probably as a result of the initial fly action) than in experiment 9; that is, the xylene had probably slowly evaporated so that by the end of the first test period the blobs produced were easily crystallized when contacted by flies. There are other possible explanations for the high level of toxicity observed in the first two test periods. One is that the *Triton X-100* emulsifier containing some dissolved DDT

Table 10.—Mortality of house flies 24 hours after exposure to various treated surfaces subjected to several combinations of environmental elements. Surfaces were tested 2, 12, 32, and 152 days after treatment with standard laboratory emulsions of residual insecticides.

Toxicant	Exposure	Surface	Mean Per Cent Mortality in Three Replicates			
			2 Days After Treatment	12 Days After Treatment	32 Days After Treatment	152 Days After Treatment
DDT	South outside	Wood	99 07	14 47	3 67	
	North outside	Wood	99 73	16 90	7 03	
	North sheltered	Wood	100 00	98 33	99 07	
	Inside	Wood	98 87	99 13	93 93	93 63
	South outside	Glass	96 17	78 27	6 00	-
	North outside	Glass	95 50	55 87	8 63	
	North sheltered	Glass	91 00	97 77	9 80	
	Inside	Glass	96 77	86 23	26 10	7 10
	South outside	Painted wood*	8 40	6 18	0 30	-
	Inside	Painted wood*	11 03	4 00	1 43	0 90
	South outside	*Cellutex*	95 90	12 47	3 33	—
	Inside	*Cellutex*	93 50	99 37	61 60	36 23
	South outside	Brick	97 00	28 10	2 97	-
	Inside	Brick	98 00	100 00	74 83	62 43
	South outside	Concrete	10 17	3 23	—	—
	Inside	Concrete	7 17	2 57	0 33	0 00
	South outside	Whitewash	13 33	2 40	—	—
	Inside	Whitewash	14 53	3 03	0 20	0 30
	South outside	Galvanized	67 33	59 63	6 10	—
	Inside	Galvanized	79 70	100 00	92 70	53 07
Chlordan	South outside	Wood	95 47	1 47		
	North outside	Wood	95 80	0 57	-	
	North sheltered	Wood	99 50	1 57	—	-
	Inside	Wood	97 67	7 63	2 00	1 70
	South outside	Glass	100 00	0 27		-
	North outside	Glass	100 00	1 30	—	
	North sheltered	Glass	100 00	88 37	5 10	—
	Inside	Glass	100 00	88 10	3 97	1 50
	South outside	Painted wood*	37 43	0 87	—	
	Inside	Painted wood*	41 43	6 43	—	—
	South outside	*Cellutex*	73 00	1 47	—	—
	Inside	*Cellutex*	65 30	7 67	—	—
	South outside	Brick	98 93	6 93	—	—
	Inside	Brick	94 80	7 10	-	
	South outside	Concrete	55 63	1 80	—	—
	Inside	Concrete	47 07	3 83	—	—
	South outside	Whitewash	66 53	1 83	—	—
	Inside	Whitewash	46 40	11.43	4 93	0 30
	South outside	Galvanized	91 23	1 53	—	—
	Inside	Galvanized	93.70	26 97	0 00	1 30

* Flat white wall paint containing vegetable oil vehicle

NOTE. Emulsions were applied at the rate of 5 ml. of 1% toxicant per square foot. Each emulsifiable concentrate consisted of 25% by weight of toxicant + 10% *Triton X-100* + 65% xylene.

Table 10 (continued)

TOXICANT	EXPOSURE	SURFACE	MEAN PER CENT MORTALITY IN THREE REPLICATES			
			2 Days After Treatment	12 Days After Treatment	32 Days After Treatment	152 Days After Treatment
Gamma isomer of hexachloro-cyclohexane	South outside	Wood	100.00	12.47	—	
	North outside	Wood	100.00	4.90	—	—
	North sheltered	Wood	99.67	3.47	—	—
	Inside	Wood	100.00	27.80	0.77	2.17
	South outside	Glass.	98.67	0.75	—	—
	North outside	Glass.	100.00	3.83	—	—
	North sheltered	Glass	100.00	11.83	0.00	—
	Inside	Glass	99.67	99.70	2.07	1.50
	South outside	Painted wood*	68.07	8.60	3.30	—
	Inside	Painted wood*	65.10	28.60	3.90	
	South outside	*Cellutex*	92.80	26.17	2.13	—
	Inside	*Cellutex*	87.37	7.37	1.13	—
	South outside	Brick	100.00	10.40		—
	Inside	Brick	99.40	7.13	—	—
	South outside	Concrete	67.77	3.10	—	—
	Inside	Concrete	65.40	1.40	—	—
	South outside	Whitewash	85.43	3.07	—	—
	Inside	Whitewash	74.37	19.17		
	South outside	Galvanized	48.80	7.37	—	
	Inside	Galvanized	43.23	3.83		—
Rhothane D-3	South outside	Wood	32.60	6.77	—	—
	North outside	Wood	37.97	0.97		—
	North sheltered	Wood	34.57	2.17	—	—
	Inside	Wood	36.27	17.47	20.43	13.73
	South outside	Glass	87.67	99.73	9.50	—
	North outside	Glass	84.93	99.43	24.47	—
	North sheltered	Glass	80.40	94.97	10.57	—
	Inside	Glass	85.97	90.87	29.97	25.00
Toxaphene	South outside	Wood	51.30	1.77	—	—
	North outside	Wood	42.40	3.67	—	—
	North sheltered	Wood	44.40	1.00	—	—
	Inside	Wood	46.37	7.60	6.13	0.63
	South outside	Glass.	100.00	0.63	—	—
	North outside	Glass	100.00	1.70	—	
	North sheltered	Glass	100.00	100.00	74.70	—
	Inside	Glass	99.73	99.77	91.57	82.97
DDT as from a 50% water-wettable powder	South outside	Whitewash	100.00	14.07	0.60	—
	Inside	Whitewash	100.00	99.67	55.4	14.90
	South outside	Painted wood*	100.00	6.80	6.83	—
	Inside	Painted wood*	100.00	7.97	5.83	0.57
	South outside	Galvanized	100.00	95.87	1.43	—
	Inside	Galvanized	100.00	100.00	95.80	89.20
	South outside	Wood	94.80	9.33	4.97	—
	Inside	Wood	95.97	93.03	91.00	58.70
Control	—	—	1.27	0.80	0.70	0.00
	—	—	1.00	0.57	0.67	0.30
Mean difference necessary for significance, 0.05 level			13.10	6.30	25.47	8.82
Mean difference necessary for significance, 0.01 level			17.29	8.32	33.66	11.80

*Flat white wall paint containing vegetable oil vehicle.

NOTE: Emulsions were applied at the rate of 5 ml. of 1% toxicant per square foot. Each emulsifiable concentrate consisted of 25% by weight of toxicant + 10% *Triton X-100* + 65% xylene.

acted as a contact poison. Another is that, previous to the first test, dust in the laboratory stimulated or seeded the drying deposit. The DDT deposits on glass or galvanized iron in all instances were more tenacious than those on porous surfaces such as wood, brick, and *Cellutex,* where erosion was significantly high. DDT on painted wood did not appear to be toxic either initially or residually. No doubt the DDT was absorbed into the paint and retained. There was no evidence in these tests that the DDT eventually bloomed, as would be expected if the solvent capacity of the oil paint were exceeded. On *Cellutex* and brick, the DDT residues were similar in longevity and erosion to those on wood. The degradation of DDT deposits was most evident upon whitewashed and concrete surfaces. In all probability the alkalinity of these substrates caused a dehydrohalogenation decomposition. DDT emulsions on galvanized iron exhibited high toxicity and longevity.

The residual longevity of the remaining four toxicants listed in tables 9 and 10 was influenced by the same external environmental degradants as was DDT, with a few exceptions that are discussed in the following paragraphs.

Chlordan-treated wood panels were little influenced by any external factors since greatest loss of chlordan was through volatilization or absorption. In the field test, where chlordan was formulated with no. 9 oil and emulsified with *Atlox 1045-A,* no erosion by rain or degradation by other elements was discernible. In experiment 10, with standardized formulations, the toxicity of chlordan on wood had declined to such a low level by the time of the first test after exposure to weathering that no conclusions were possible. In contrast, erosion of chlordan by rain was plainly evident on glass panels. When no. 9 oil (experiment 9) was used as the diluent, the residual toxic life of a chlordan deposit was at least twice as long as when a xylene formulation (experiment 10) was employed. Similarly, when *PD 544-C* was used as the solvent (experiment 9), the residual toxicity of a hexachlorocyclohexane deposit was longer than when a xylene was employed (experiment 10).

Gamma hexachlorocyclohexane also reacted to its environment in a manner similar to the action of DDT, but hexachlorocyclohexane degraded rapidly out of doors or in strong wind currents. Most of its loss was attributed to its volatility.

Rhothane D-3 was significantly more tenacious on glass than on wood, and responded to its environment in much the same manner as did DDT.

Toxaphene lost its toxicity on wood much more rapidly than on glass panels held in the laboratory. Simple physical absorption of *Toxaphene* by the wood is suggested as an explanation.

Experiment 11: ***Formulation Studies.***—The data obtained in the laboratory study of the persistence of oil solutions, emulsions, and suspensions are given in table 11. Studies of duration of residual toxicity were conducted to see if any one formulation was more persistent on the hazardous surfaces—whitewashed wood, concrete, and painted wood—that cause apparently rapid loss of toxicity. The results show that water-wettable powders were generally superior to the other formulations on all these surfaces.

The initial toxicity of oil solutions and emulsions of DDT, as evidenced by the data in table 11, was very low on whitewashed wood, painted wood, concrete, and unpainted wood, and very high on glass. The results here are similar to others in this study, which indicate that oil solutions or emulsions of DDT are low in toxicity on porous surfaces and very high on hard, smooth surfaces, such as glass, if tested before crystals have started to form.

The second test period 7 days after treatment gave high fly mortalities on wood panels and lower on glass panels. The water-wettable powders of DDT were significantly more toxic on painted wood, whitewashed wood, and concrete than were the oil solutions or emulsions. Even with the wettable powder the alkalinity of the whitewash and concrete must have reached the DDT to cause a decline in the toxicity. This action was probably accomplished through adsorbed water. On painted wood the toxicity decreased without any apparent reason; a possible explanation is that the oils in the underlying paint were capable in some manner of penetrating the wettable powder and dissolving away the DDT. On glass and

Table 11.—Mortality of house flies 24 hours after exposure to various surfaces treated with oil solutions, emulsions, and water-wettable powders of DDT and chlordan. Flies were exposed to surfaces 1, 7, and 45 days after the surfaces had been treated.

Residual Insecticide Formulation	Surface	Mean Per Cent Mortality in Three Replicates		
		1 Day After Treatment of Surface	7 Days After Treatment of Surface	45 Days After Treatment of Surface
DDT oil solution	Whitewash	0.0	0.6	0.0
	Painted wood*	4.9	3.5	2.2
	Concrete	0.0	1.7	0.0
	Glass	100.0	77.9	75.8
	Wood	10.7	100.0	99.4
DDT emulsion	Whitewash	0.6	4.2	0.4
	Painted wood*	1.1	2.6	0.0
	Concrete	0.6	1.2	0.0
	Glass	95.5	35.1	24.6
	Wood	3.5	98.6	94.4
DDT suspension	Whitewash	100.0	92.9	32.9
	Painted wood*	100.0	28.0	2.5
	Concrete	99.7	41.2	12.2
	Glass	100.0	100.0	91.2
	Wood	98.3	96.6	83.2
Chlordan oil solution	Whitewash	95.7	32.9	0.3
	Painted wood*	4.5	8.1	0.0
	Concrete	16.8	5.8	0.0
	Glass	100.0	23.8	2.2
	Wood	99.4	34.5	1.0
Chlordan emulsion	Whitewash	84.3	31.6	6.6
	Painted wood*	93.0	1.6	0.3
	Concrete	42.7	4.8	0.0
	Glass	99.3	81.9	2.8
	Wood	100.0	27.0	0.3
Chlordan suspension	Whitewash	69.0	27.5	2.5
	Painted wood*	92.9	12.1	4.2
	Concrete	41.0	7.1	0.5
	Glass	100.0	5.2	0.5
	Wood	100.0	37.9	1.9
Control	--	0.60	1.90	0.00
	--	1.00	0.90	0.90
Mean difference necessary for significance, 0.5 level		5.53	3.78	8.46
Mean difference necessary for significance, 0.1 level		7.37	5.04	11.26

* Flat white wall paint containing vegetable oil vehicle

wood panels the toxicity of the wettable powders remained at a high level.

There was no important advantage in using a chlordan water-wettable powder on surfaces where DDT water-wettable powder was superior to the DDT emulsion and oil solutions. In fact, upon glass the chlordan water-wettable powder was significantly less effective than were the oil solutions and emulsions. The reason for the short residual action of the chlordan water-wettable powder on glass may have been associated with the greater surface area of the finely divided powder, responsible for a rapid rate of loss through evaporation. The greater loss of toxicity from the glass panels treated with chlordan oil solutions, in contrast to the emulsions, was perhaps influenced by an increase in surface area produced by a continuous film. The emulsions left a discontinuous film, which was not so subject to evaporation.

In addition, the emulsions had an emulsifier of high vapor pressure, which retards chlordan evaporation.

Experiment 12: ***Laboratory Persistence of Deposits.***—A plan was made to test more fully the residual properties of the three most promising toxic residual materials. At frequent intervals during a 31-day period, house flies were exposed for 15-minute periods to panels treated with DDT and gamma hexachlorocyclohexane and for 60-minute periods to panels treated with chlordan. The results are shown in table 12. The order of persistence on wood or glass was, from the most persistent to the least, DDT, chlordan, and gamma hexachlorocyclohexane. The suspension of hexachlorocyclohexane retained its toxicity at a high level for 10 days; then its toxicity declined rapidly. Chlordan lost its toxicity gradually through the test period, whereas DDT emulsion on wood seemed to increase in effectiveness.

The lower toxicity exhibited by the emulsion of DDT and *PD 544-C* on glass than on wood from the first day to the last is typical of DDT residues in which a slowly volatilizing solvent is used and crystallization is progressive. In other words, the frequent exposure of flies to these surfaces did not permit sufficient supersaturated fluid to accumulate, which is essential for the production of high toxicity residues composed of minute crystals. Again, a physical law determining crystal size was responsible for the toxicity attained. The number of crystals per unit mass is directly proportional to the rate of crystallization, which is dependent upon the degree of supersaturation. Blooming of DDT on wood occurred between the second and sixth days and produced a residue that remained toxic throughout this experiment.

The thick white residue of the gamma hexachlorocyclohexane water-wettable powder was slightly more toxic and persistent when applied to glass than to wood. The longevity of the chlordan and hexa-

Table 12.—Mortality of house flies 24 hours after exposure to wood and glass panels treated with DDT, hexachlorocyclohexane, and chlordan. Flies were exposed to treated surfaces at designated periods of time after the surfaces had been treated.

Insecticide	Deposit of Toxicant in Mg. per Square Foot	Surface	Replicate No.	Per Cent Mortality 24 Hours After Exposure to Surface Stated Number of Days After Treatment of Surface								Exposure Time in Minutes
				1	2	4	6	10	12	24	31	
DDT emulsion	50	Wood	1	37	40	57	93	91	100	100	100	15
	50	Wood	2	49	48	60	96	81	75	85	100	15
	50	Wood	3	21	49	97	100	100	100	100	100	15
			Mean	35.7	45.7	71.3	96.3	90.7	91.7	95.0	100.0	—
	50	Glass	1	46	27	18	22	20	16	22	12	15
	50	Glass	2	76	24	19	15	15	13	12	13	15
	50	Glass	3	56	31	19	27	30	17	16	15	15
			Mean	59.3	27.3	18.7	21.3	21.7	15.3	16.7	13.3	—
Gamma isomer (5.2 per cent) hexachloro-cyclohexane in a water-wettable powder	50	Wood	1	99	98	54	74	56	12	6	2	15
	50	Wood	2	100	96	65	86	43	17	7	3	15
	50	Wood	3	94	94	66	77	40	16	10	2	15
			Mean	97.7	96.0	61.7	79.0	46.3	15.0	7.7	2.3	—
	50	Glass	1	100	100	100	100	84	71	21	8	15
	50	Glass	2	100	100	100	100	100	81	16	4	15
	50	Glass	3	100	100	100	100	90	86	10	0	15
			Mean	100.0	100.0	100.0	100.0	91.3	79.3	15.7	4.0	—
Chlordan emulsion	50	Wood	1	96	92	75	69	62	54	19	15	60
	50	Wood	2	98	95	80	77	60	33	22	6	60
	50	Wood	3	92	88	57	54	50	18	17	11	60
			Mean	95.3	91.7	70.7	66.7	57.3	35.0	19.3	10.7	—
	50	Glass	1	100	100	52	52	34	19	9	0	60
	50	Glass	2	100	100	52	55	33	25	14	3	60
	50	Glass	3	100	100	74	67	45	17	17	7	60
			Mean	100.0	100.0	59.3	58.0	37.3	20.3	13.3	3.3	—

chlorocyclohexane residues was nearly equal. Chlordan seemed slightly more lasting on wood, and hexachlorocyclohexane lasted longer on glass.

In this particular experiment, table 12, chlordan was of about equal effectiveness on wood and on glass, while in most of the previous work the chlordan emulsion residue on glass gave more lasting toxicity than on wood. If an explanation of these results is desired, it might be found in the difference in the composition of the wood panels or the environment in which the panels were held. The cause of the degradation of chlordan on glass was attributed to dust and debris that accumulated upon the oily surface. In the experiment described above, dust and debris left on the surface by the flies may have been more important than that floated in by air currents. Not only will dust and dirt mask the chlordan, but may assist evaporation by increasing the evaporation area just as with water-wettable powder (experiment 11). It is not beyond reason to believe that the chlordan-treated glass surface was roughened by the fly contacts of the frequent exposures, resulting in greater surface area for evaporation. Also, the higher initial toxicity of chlordan-treated panels suggests a greater loss incurred by physical contact of the flies.

Experiment 13: *Laboratory Study of DDT Emulsion on Glass and Wood.*—The results of experiments summarized in table 12 seemed to indicate some peculiar properties of the initial toxicity of DDT emulsions on glass and wood. Another experiment was undertaken to broaden the scope of the investigation. This involved a closer study of the initial toxicity periods. Consequently, data were obtained from deposits of DDT that were less than 1 day old. The results obtained, summarized in table 13, disclose the "blooming out" (crystallization of DDT on the surface) period of DDT on wood and reveal in the treatment on glass the loss of toxicity that occurred as the emulsion dried.

In this experiment, as in previous tests, no toxic bloom of fine powdery crystals occurred on glass, since fly stimulation and seeding of surface were too frequent to permit the accumulation of supersaturated solvents. Consequently, there was a gradual formation of large crystals of low toxicity. The greatest fly mortality from exposures to glass panels occurred before any DDT crystals were found; the opposite was true in the case of DDT emulsions on wood. Besides the seeding action by flies, many environmental components may influence the rate and kind of DDT bloom to appear on a surface. The same solvent may yield large crystals one day, and the next day, when the temperature is higher and air movements greater, it may produce small crystals.

Experiment 14: *Approximate Residual Toxicity of Several New Insecticides to the House Fly.*—Several new insecticides that have recently come under study are briefly considered here and compared with DDT and chlordan. Ten per cent solutions of *Marlate* (4,4′-dimethoxy-diphenyl trichloroethane), *V-4* (diethyl *p*-nitrophenyl phosphate), *Pyrenone* (actually 10 per cent piperonyl butoxide and 0.5 per cent pyrethrins), *118* (1,2,3,4,10,10-hexachloro-1:4, 5:8-diendomethano-1,4,4a.5,8,8a-hexahydronaphthalene), parathion (diethyl *p*-nitrophenyl thiophosphate), heptaklor 1 (or 3a),4,5,6,7,8,8-heptachloro-3a,4,7,7a-tetrahydro-4,7-methanoindene, and *497* (oxygen

Table 13.—Mortality of house flies exposed 15 minutes to wood and glass panels at stated intervals after treatment of panels with 1 per cent DDT emulsion.

Deposit of DDT in Mg. per Square Foot	Surface	Replicate	Per Cent Mortality 24 Hours After Exposure to Surface Stated Period of Time After Treatment of Surface						
			4 Hours	8 Hours	1 Day	3 Days	5 Days	17 Days	24 Days
50	Wood	1	4.1	13.4	29.0	100.0	100.0	100.0	100.0
50	Wood	2	3.9	14.5	47.5	100.0	100.0	100.0	100.0
50	Glass	1	100.0	59.0	36.0	29.1	21.9	22.0	15.9
50.	Glass	2	100.0	66.0	58.0	75.0	28.0	21.6	12.1

analogue of *118*) in *Velsicol AR-60* (methylated naphthalenes) were sprayed in triplicate upon glass and wood panels to produce deposits of 50 mg. per square foot. Flies were exposed for 30-minute periods to these panels each week until the toxicants had degraded to a low level. One set of three panels of wood and glass was exposed to direct sunlight and wind but protected from rain; a similar set was kept in the laboratory.

Table 14 was designed to help evaluate the residual activities of the toxicants in periods of weeks needed to degrade a deposit to 50 per cent of its initial toxicity.

Table 14.—Approximate number of weeks required for residual insecticides to degrade to 50 per cent of their initial toxicity to house flies. Flies were exposed 30 minutes to each panel which had been treated with insecticide at the rate of 50 mg. per square foot of treated surface.

Material Dissolved in *Velsicol AR-60*	Outside		Inside	
	Wood	Glass	Wood	Glass
Marlate	1 5	1 0	4 5	2 0
V4.	1 0	1 5	7 5	14 5
Pyrenone	0 5	0 5	2 5	4 5
DDT	4 0	2 0	12 0	5 5
118	1 0	1 0	5 5	1 5
Parathion	0 5	0 5	1 5	2 0
Heptaklor	1 5	1 0	5 5	1 5
Chlordan	1 0	1 0	5 0	2 0
497	—		10 0	7 0

The residual values of the volatile toxicants in particular were extended by the relatively nonvolatile solvent, *Velsicol AR-60*. Experiments with *Pyrenone* in xylene gave a 50 per cent degradation value on glass in only 1.25 weeks; *Pyrenone* in *Velsicol AR-60* required 4.5 weeks for 50 per cent degradation. Similarly, chlordan in xylene had a 50 per cent degradation value on wood in 2 weeks; chlordan in *Velsicol AR-60* required 5 weeks in the experiment described above to sink to the same degradation value. The same kind of solvent effect was noted in experiments described earlier in this study. Undoubtedly there are, among the insecticides listed in table 14, toxicants that would serve well as substitutes for DDT when house-fly tolerance for DDT becomes too high to effect practical control.

SUMMARY

DDT, gamma hexachlorocyclohexane, chlordan, *Rhothane D-3,* and *Toxaphene* were applied on various surfaces and exposed to different environmental conditions in several experiments to determine their residual toxicities to the house fly, *Musca domestica* Linnaeus. The toxicities of the residues were determined by exposing the flies in specially constructed exposure cages to the treated surfaces for certain periods of time and holding the flies for a 24-hour mortality count.

The conclusions for the experiments herein reported are as follows:

1. DDT and gamma hexachlorocyclohexane were initially the most toxic compounds. The other three materials were, in order of their diminishing toxicity, chlordan, *Rothane D-3,* and *Toxaphene.*

2. Hexachlorocyclohexane gave the most rapid knockdown, followed by DDT, *Rhothane D-3*, chlordan, and *Toxaphene.*

✓ 3. Degree of coverage of surface affected mortality more than the dosage variations or uneven distribution of DDT.

4. A wall coat containing 5 per cent DDT (formulated from a 25 per cent DDT emulsifiable concentrate) was nearly as effective on wood as 50 per cent water-wettable DDT powder.

5. When DDT water-wettable powder was applied at different dosages to glass, a dosage mortality relationship was not evident above 12.5 mg. toxicant per square foot; a dosage range of 12.5 to 200.0 mg. resulted in nearly 100 per cent mortality. Below 12.5 mg. a typical sigmoid dosage-mortality curve was obtained.

6. In fly-erosion tests, there was little significant difference in fly mortality among 10 cages exposed successively to the same deposit of 50 mg. DDT per square foot.

7. Fly erosion was noticeable in tests with *Deenate* water-wettable powder on glass and xylene-DDT, *Velsicol AR-60*-DDT, and *HB-40*-DDT emulsions on wood, except when secondary blooming occurred.

8. Secondary or seeded blooms that occurred with certain formulations were very toxic and resisted fly erosion. On wood, those DDT emulsion formulations containing *PD 544-C* or xylene (with either ethyl-

ene dichloride or carbon tetrachoride) as the solvents produced exceedingly heavy mats of very fine crystals of high toxicity when seeded by fly activity. Bone glue 5 per cent, added to *Deenate* water-wettable powder improved tenacity. DDT, 1.26 per cent, in 95 per cent ethyl alcohol when applied to glass produced a deposit of extremely fine crystals of high toxicity and tenacity.

9. DDT-xylene emulsion deposits on glass or wood when seeded early (within 2 days after application) produced a fairly effective secondary bloom.

10. High toxicity and tenacity of deposits were associated with the fineness of DDT crystallization upon the surface.

11. No difference in toxicity or tenacity of deposits could be attributed to the method of application (spraying or painting).

12. Vapors from gamma hexachlorocyclohexane were about three times as toxic to flies as those from chlordan; both were extremely toxic as fumigants. The fact that toxic vapors are given off from chlordan and hexachlorocyclohexane deposits accounts for their short-lived residual action on exposed surfaces.

13. Solvents of low volatility increased the residual toxicity of the more volatile insecticides.

14. DDT was the most persistent insecticide tested. The residual toxicity of DDT emulsions was better indoors on porous surfaces, such as wood, brick, and *Cellutex*, than on glass and galvanized iron. Out of doors, residues were more persistent on the nonporous glass and galvanized iron panels.

15. The order of persistence of the residual treatments was, from the most to the least, DDT, *Rhothane D-3*, *Toxaphene*, chlordan, and hexachlorocyclohexane.

16. The oil solutions and emulsions of the chlorinated hydrocarbons were relatively nontoxic to flies when applied to whitewash, painted wood, and concrete. Water-wettable powders produced effective residual deposits on these same three surfaces.

17. Sunshine, rain, and wind were found to be significant climatic factors in the degradation of the residual surface toxicities of the materials tested. Wind was apparently the least significant of the three.

18. With a few exceptions, when DDT emulsions were applied to wood, the toxicity increased as the DDT "bloomed out"; when the emulsions were applied to glass, the toxicity decreased as the emulsions dried and crystals formed parallel to the glass surface.

19. In a study on newer insecticides, *V4* and *497* on wood and glass produced residues of significant longevity with high toxicity. Other materials tested were less persistent.

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Effect of
Permanent Flooding in a River-Bottom Timber Area

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CONTENTS

In the Calhoun County, Illinois, study area, permanently flooded in 1938, pin oaks and other tree species having durable heartwood characteristically lost their branches and later their sapwood, leaving standing skeletons of heartwood.

Effect of Permanent Flooding

in a River-Bottom Timber Area

LEE E. YEAGER*

WATER impoundments, varying from simple fish ponds to the vast programs now being sponsored by the United States Corps of Engineers and the Bureau of Reclamation, involve many changes in the American landscape. Practically every major stream and hundreds of smaller ones have been or, if present proposals are consummated, will be affected by dams erected for power development, channel improvement, flood and erosion control, and other purposes. The environmental effects inherent in this nation-wide program are potentially of great importance to wildlife, inland fisheries, bottomland forests, and agriculture.

One of the problems associated with stream damming and resultant impoundments is that of flooded timberland. On many projects, especially where public funds are involved, the areas to be flooded are cleared of trees and brush. On others, clearing may be done only partly or not at all, because of shortage of funds, or because of bad weather, high water, or other reasons. Flood-killed timber is generally considered by the public as unsightly, and complaints concerning it may be strong. Dead trees that reach navigable streams after falling offer certain hazards to shipping, commercial fishing and other enterprises associated with inland waterways. Therefore, whether from the standpoint of aesthetics or economics, flood-killed timber is a problem, and one having a strong probability of increasing in importance.

The objective of the study on which the present report is based was to determine the rate of flooding mortality in various Mississippi River valley tree species and the rate and effect of tree fall; in the course of the study, brief consideration was given to plant and animal succession following the death of timber stands. The report covers principally the period beginning in September, 1939, and ending in October, 1946.

* Formerly Forester, Illinois Natural History Survey, Urbana, Illinois. Since May, 1945, with the United States Fish and Wildlife Service, present station, Leader, Colorado Co-operative Wildlife Research Unit, Colorado Agricultural and Mechanical College, Fort Collins, Colorado. The major portion of the investigation on which the present paper is based was made while the author was employed by the Natural History Survey. Completion of the study was accomplished through a co-operative arrangement between the Survey and the Fish and Wildlife Service.

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My obligations for assistance during this investigation are many. I am indebted, first of all, to the late Dr. Theodore H. Frison, former Chief of the Illinois Natural History Survey, who proposed the study. To Dr. Leo R. Tehon, during part of the study period, Acting Chief of the Natural History Survey, and to Dr. Gustav A. Swanson, formerly with the Fish and Wildlife Service, I owe thanks for the co-operative arrangement wherein I was permitted to complete field observations. Dr. Tehon aided in planning the investigation and Mr. G. H. Boewe, also of the Survey staff, assisted with initial field work. Dr. Cornelius H. Muller, while with the Natural History Survey as a botanist, made the detailed vegetation map on which later work was based. For data used in preparing fig. 5, I am indebted to the St. Louis District, Corps of Engineers, Department of the Army. Several wildlife specialists of the Natural History Survey or co-operating organizations gave valuable help: Mr. Charles S. Spooner, Jr., was of much assistance in mapping; Mr. Frank C. Bellrose, Dr.

Ralph E. Yeatter, Mr. Harry G. Anderson, Mr. Charles McGraw, and Mr. Willet N. Wandell provided numerous records and were helpful in other ways; and Mr. Robert G. Rennels made careful analysis of food-habits material. Mr. Carl Pohlman, a resident of Calhoun County, gathered valuable records on the fur take. Mr. James S. Ayars, Mr. Robert E. Hesselschwerdt, and Dr. H. H. Ross, editor, photographer, and systematic entomologist, respectively, of the Illinois Natural History Survey, are responsible for most of the photographs used here as illustrations. Mr. Ayars' assistance with editorial problems is gratefully acknowledged.

AREA STUDIED

Detailed work forming the background for the present report was done on the Pere Marquette Wildlife Experimental Area, locally known as Calhoun Point, in Calhoun County, Illinois, fig. 1. Calhoun Point was formed by the confluence of the Mississippi and Illinois rivers.

At other than flood periods, previous to 1938, the 2,200-acre Pere Marquette area, roughly 1 by 4 miles, was characterized by numerous wooded ridges, flats, and wet-weather sloughs, several small lakes, a number of small marshes, and the margins of two large rivers. In June, 1938, gates of the recently completed Alton Dam, 20 miles downstream on the Mississippi River, were closed for the first time. This closure resulted in flooding several hundred acres of the area, normally land. Although the gates were opened a few times after June, 1938, the higher than normal water level that prevailed through much of the 1938 growing season, fig. 5, was sufficient to affect plant species sensitive to flooding.

By the summer of 1939, 600 acres (27 per cent) of the area were permanently inundated; 1,600 acres (73 per cent) lay above pool level, which was 15.3 feet

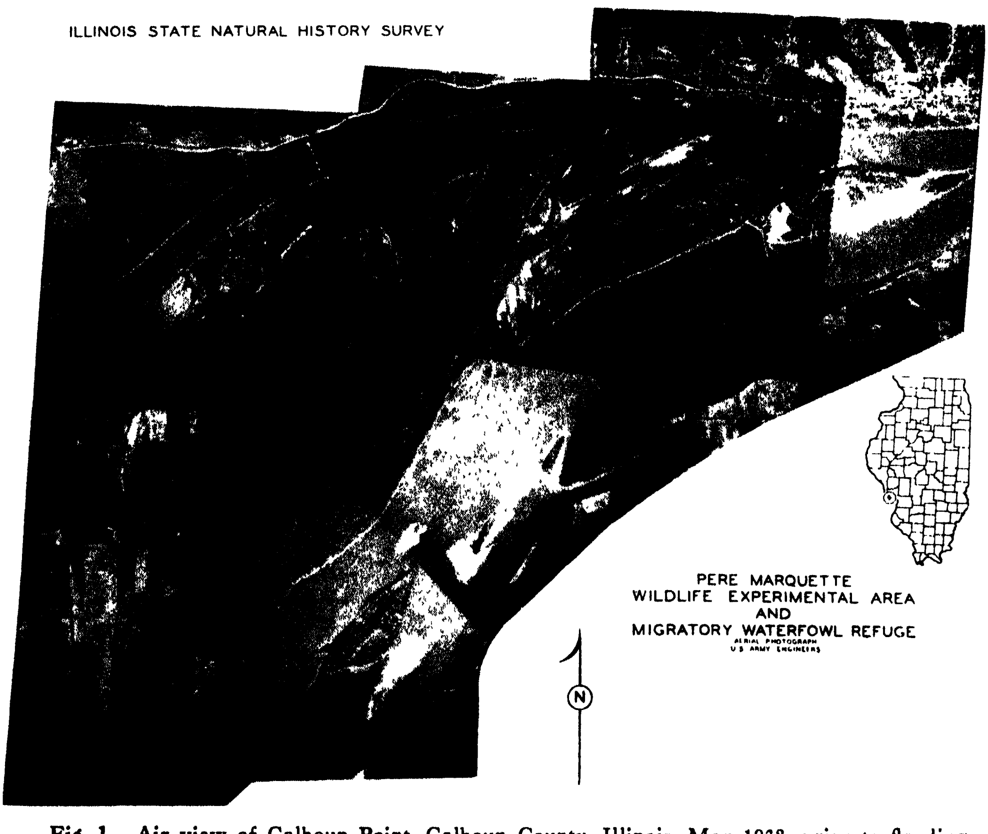


Fig. 1.—Air view of Calhoun Point, Calhoun County, Illinois, May 1938, prior to flooding.

at Grafton, 2 miles downstream. Prior to the Alton impoundment, annual fluctuation of the Mississippi and Illinois rivers in the locality varied from subgage lows to floods exceeding 25 feet. Even after the impoundment, severe floods occurred in 1943 and 1944 and a lesser flood in 1945. Permanent flooding increased the average summer water stage by about 3 feet. Maximum elevation on the area before impoundment was 10 feet; at pool level, after impoundment, the highest ridges were only 7 feet above the water surface. These figures indicate the very low relief of the Pere Marquette area.

STUDY PROCEDURE

Basic to the work reported here was a detailed vegetation map of the area prepared by Cornelius H. Muller while with the Natural History Survey's Section of Applied Botany and Plant Pathology. Muller did his field work between February 8 and June 11, 1938, shortly before initial flooding of the area was begun. In mapping the area, he established 11 transects, each 50 feet wide, that varied in length from 600 feet to 1.1 miles and totaled 5.9 miles.

Muller established the transects after he had made a general reconnaissance map of the many minor vegetation types distinguishable. He did not space the transects uniformly or orient them parallel with each other, but laid them out to cross as many as possible of the water channels and sloughs then present on the area and to traverse in a representative way as many as possible of the vegetation types.

He mapped the transects in such detail as to show the location of all trees, all large shrubs, and most of the herbaceous plant areas within them, recording species (substantiated by specimens deposited in the Illinois Natural History Survey herbarium), diameters of trees, sizes of shrubs, and density of herbaceous cover.

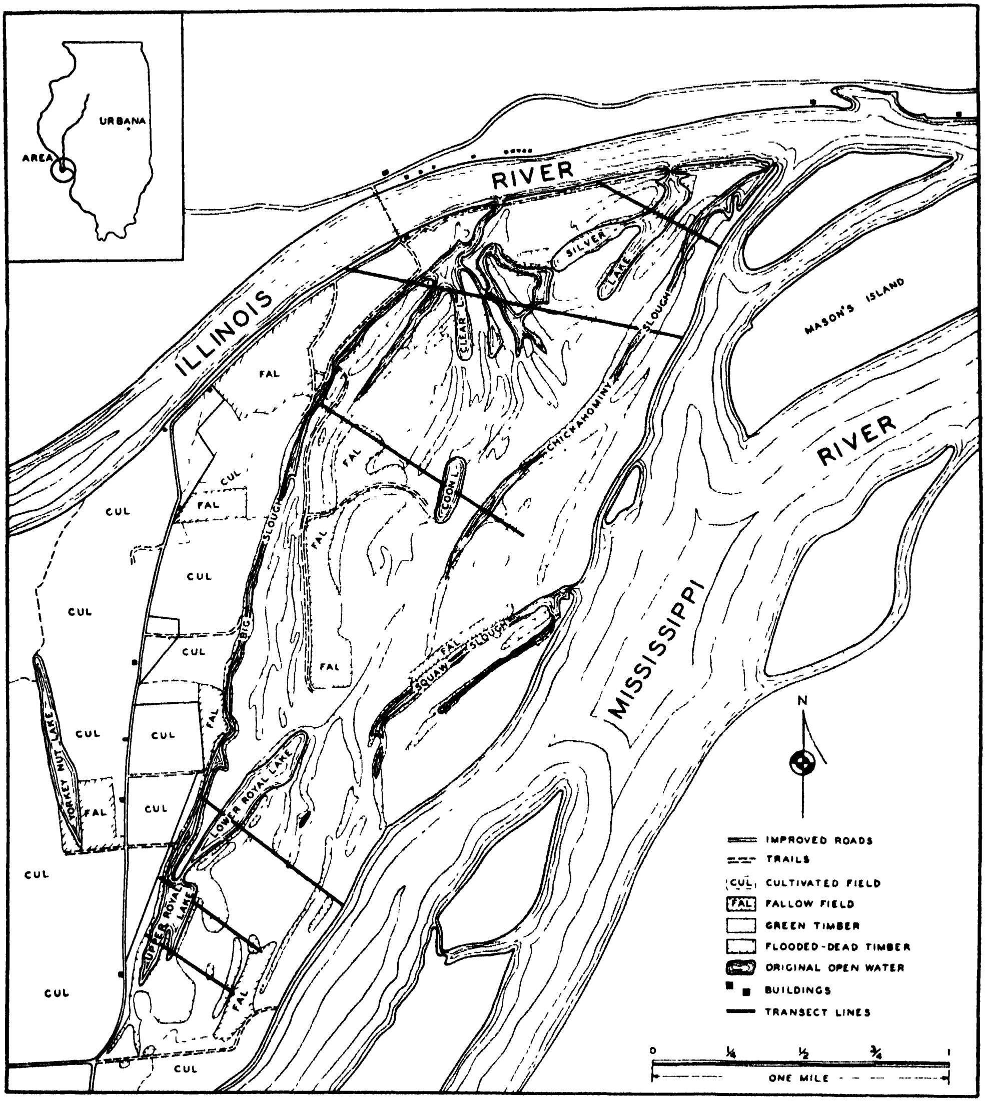
The location of six transects, 1, 2, 6, 7, 8, and 11, totaling 3.5 miles, is shown in fig. 2. These transects constitute the sample used as a basis for the present paper.

Active field work on the effect of flooding was begun in September, 1939, about 3 months after the date of permanent inundation. (The Alton Dam had been closed during the summer and a part of the fall of 1938, fig. 5.) The first records taken by the writer were before any of the trees had died, although the pin oaks and a few trees of other species showed effects of an abnormally high water stage.

In the six sample transects, 1, 2, 6, 7, 8, and 11, each living tree and shrub, regardless of species, size or condition, was tagged for future inspection, except in pure stands of maple or elm on land, or in large clumps of waterprivet or buttonbush in water, where only every second, third, or fifth tree or shrub was tagged. Markers or tags were of 14-gage galvanized sheet metal, about 1 by 2 inches in size, each perforated at one end, and numbered consecutively. Attachment was by means of sixpenny galvanized nails, at a height of about 4.5 feet. In each transect the tags faced one direction, always that opposite to the direction of progress, thus facilitating both attachment and relocation. Transects were marked at each end and at varying intervals by appropriately numbered signs.

Records made at the time tags were attached and at all succeeding inspections were kept on the same form. At the first inspection, made when tags were attached, the number was recorded for each tree, and with it the tree species, d.b.h., crown class, and general vigor as near as this could be estimated. Where water occurred, the depth at the base of each tagged tree was recorded. At each succeeding inspection, the condition of the tree and the water depth, which varied as shown in fig. 5, were the main records taken. Trees obviously dying, but still with green leaves or cambium, were so recorded. Observations were made in June and October, 1940; one record was taken in June, 1941, one in October, 1942, and another in October, 1944, table 2. The final record was taken in October, 1946. A total of six inspections, in addition to those at the time of tagging and on numerous visits at other seasons, supplied data for this report.

Supplementing the detailed investigation in the Pere Marquette area were observations made in flooded areas along the



PERE MARQUETTE WILDLIFE EXPERIMENTAL AREA
GRAFTON, ILLINOIS

Fig. 2.—Land and water areas on the Pere Marquette Wildlife Experimental Area, Calhoun Point. Orientation of the six transects supplying sample data is shown by straight, heavy lines. The direction of flow of the Illinois and Mississippi rivers in this area is approximately northeast.

Mississippi River in Jo Daviess, Henderson, and Pike counties, and along the Illinois River in Mason and Jersey counties, all in Illinois. These areas were similar to Calhoun Point except that they were narrower, were bordered by large rivers along only one side, and supported greater proportions of willows and cottonwoods in the stands. The supplementary observations, confirmatory in nature, are not incorporated in this report.

Common and scientific nomenclature in this paper is, in most instances, based on the following authorities: Kelsey & Dayton (1942) for plants; Necker & Hatfield (1941) for mammals; American Ornithologists' Union (1931) for birds. Some forms were not identified to species.

TIMBER TYPES

Most of Calhoun Point, at the time of permanent flooding, was covered by river-bottom forest characteristic of that found in the upper Mississippi River valley. The stands, varying from sapling to mature growth, contained scores of very large, decadent, and often dying silver maples, with an occasional elm, sycamore, and pin oak of similar type, fig. 3. Composition, size classes, and the scientific names of all important trees and shrubs contained in the samples are indicated in table 1.

Silver or soft maple was the most abundant of the large trees in the flooded area. On the lowest level on which trees grew, it easily dominated all plants except semiaquatic species, such as black willow, buttonbush, waterprivet, and waterlocust, fig. 4. Many of the maple

Fig. 3.—Huge, overmature, and characteristically multibranched maples, elms, oaks, and sycamores were found in the Calhoun Point stands, October, 1940.

Table 1.—Number of trees on land, in mud, and in water, in six 50-foot transects totaling 3.5 linear miles, in study area, Calhoun County, Illinois, October, 1939.

Species*	Diameter Classes, Inches																					Total			
	1–2			3–5			6–10			11–15			16–20			21–25			26 and over						
	Land	Mud	Water	Land	Mud	Water	Land	Mud	Water	Land	Mud	Water	Land	Mud	Water	Land	Mud	Water	Land	Mud	Water	Land	Mud	Water	All Trees
Maple, silver (*Acer saccharinum*)	0	1	0	9	6	21	69	17	43	93	16	40	26	6	38	0	2	17	19	7	18	216	55	177	448
Elm, American (*Ulmus americana*)	0	0	0	12	5	9	43	20	55	25	6	29	7	4	6	4	0	0	7	2	5	98	37	104	239
Ash, white (*Fraxinus americana*)	1	1	2	11	5	8	27	6	8	7	1	5	4	1	3	5	2	3	4	2	2	59	18	31	108
Oak, pin (*Quercus palustris*)	0	0	0	4	0	0	10	0	1	12	3	11	4	1	3	5	1	4	11	0	9	46	5	28	79
Pecan (*Carya illinoensis*)	0	0	0	2	0	0	10	0	3	17	2	15	14	0	6	2	0	1	1	0	1	46	2	26	74
Waterprivet (*Forestiera acuminata*)	6	2	22	12	3	24	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	18	5	47	70
Persimmon, common (*Diospyros virginiana*)	0	0	0	5	1	7	6	1	14	16	3	13	0	0	1	0	0	0	0	0	0	27	5	35	67
Waterlocust (*Gleditsia aquatica*)	1	0	0	3	1	5	3	1	3	1	0	10	9	0	4	4	0	3	3	0	0	24	2	25	51
Hackberry, sugar (*Celtis laevigata*)	0	0	0	6	0	2	28	2	0	9	1	1	1	0	0	1	0	0	0	0	0	45	3	3	51
Hawthorn (*Crataegus* spp.)	0	0	0	10	2	5	6	1	7	1	1	4	0	0	0	0	0	0	0	0	0	17	4	16	37
Willow, black (*Salix nigra*)	0	0	1	0	0	4	0	0	13	0	0	4	0	0	1	0	0	0	0	0	0	0	0	23	23
Birch, river (*Betula nigra*)	1	1	0	1	1	1	0	0	4	1	0	4	1	0	5	0	0	2	0	0	1	4	2	17	23
Boxelder (*Acer negundo*)	1	0	0	1	0	0	9	0	0	8	0	0	1	0	0	0	0	0	0	0	0	20	0	0	20
Mulberry, red (*Morus rubra*)	0	0	0	6	0	0	8	0	0	1	0	0	0	0	0	0	0	0	0	0	0	15	0	0	15
Buttonbush, common (*Cephalanthus occidentalis*)	0	0	14	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	15
Cottonwood (*Populus deltoides*)	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	2	1	4	2	0	5	5	1	9	15
Holly (*Ilex decidua*)	3	1	7	3	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	1	8	15
Oak, bur (*Quercus macrocarpa*)	0	0	0	1	0	0	0	0	3	0	0	1	2	0	1	0	0	0	0	0	0	3	0	5	8
Sycamore, American (*Platanus occidentalis*)	0	0	0	1	0	0	1	0	0	2	0	0	0	0	0	1	0	0	1	0	0	6	0	0	6
Dogwood flowering (*Cornus florida*)	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	2
Plum, American (*Prunus americana*)	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Elm, slippery (*Ulmus fulva*)	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Coffeetree, Kentucky (*Gymnocladus dioicus*)	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Redbud, eastern (*Cercis canadensis*)	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Total	13	6	46	91	24	88	222	48	155	194	33	137	69	12	68	24	6	34	48	11	41	661	140	569	1,370

* Technical names from *Standardized Plant Names*, second edition, 1942, with few exceptions; common names [illegible] from same source.

flats held standing water during the rainy seasons. Maple was also a dominant species on some higher sites, including unflooded ridges. American elm, pecan, and sugar hackberry reached their best development at slightly higher elevations. Ash was often found on lower sites occupied principally by maple, but occurred at all elevations. Species of secondary importance on elm-ash-pecan sites included persimmon, river birch, hawthorn, and holly.

On the highest land flooded, originally the lower ridges, pin oak, persimmon, cottonwood, and several less important species were found. Waterlocust grew mainly on shore lines but sometimes on ridge sites; waterprivet and buttonbush were confined to shore lines and shallow sloughs, both species often occurring in a foot or more of water. Found on unflooded land, particularly on the higher ridges, were boxelder, red mulberry, redbud, dogwood, American plum, honey locust, and Kentucky coffeetree, none of which appeared on the flooded portion of the samples, table 1.

Fig. 4.—Typical stand of silver maple on a "flat" site, October, 1940. Dead and dying trees in background.

The Pere Marquette area is north of the range of baldcypress and water tupelo *(Taxodium distichum* and *Nyssa aquatica)* and evidently of certain other southern river-bottom species, such as blackgum *(Nyssa sylvatica)*, American sweetgum *(Liquidambar styraciflua)*, and the magnolias *(Magnolia* spp.), which were not represented. The area lies considerably south of the midwestern occurrence of tamarack *(Larix laricina)*, spruce *(Picea* spp.), balsam fir *(Abies balsamea)*, and northern white-cedar *(Thuja occidentalis)*. Black ash *(Fraxinus nigra)*, which occurs in Illinois, was not found in the area.

WATER LEVELS

That the water stage at Calhoun Point, even after closing of the Alton Dam, fluctuated considerably is shown in fig. 5. Fluctuation was due in part to winter drawdowns in 1938–39 and 1939–40, to unusually high floods during the springs of 1943 and 1944, and to a less severe flood in the spring of 1945. Several minor

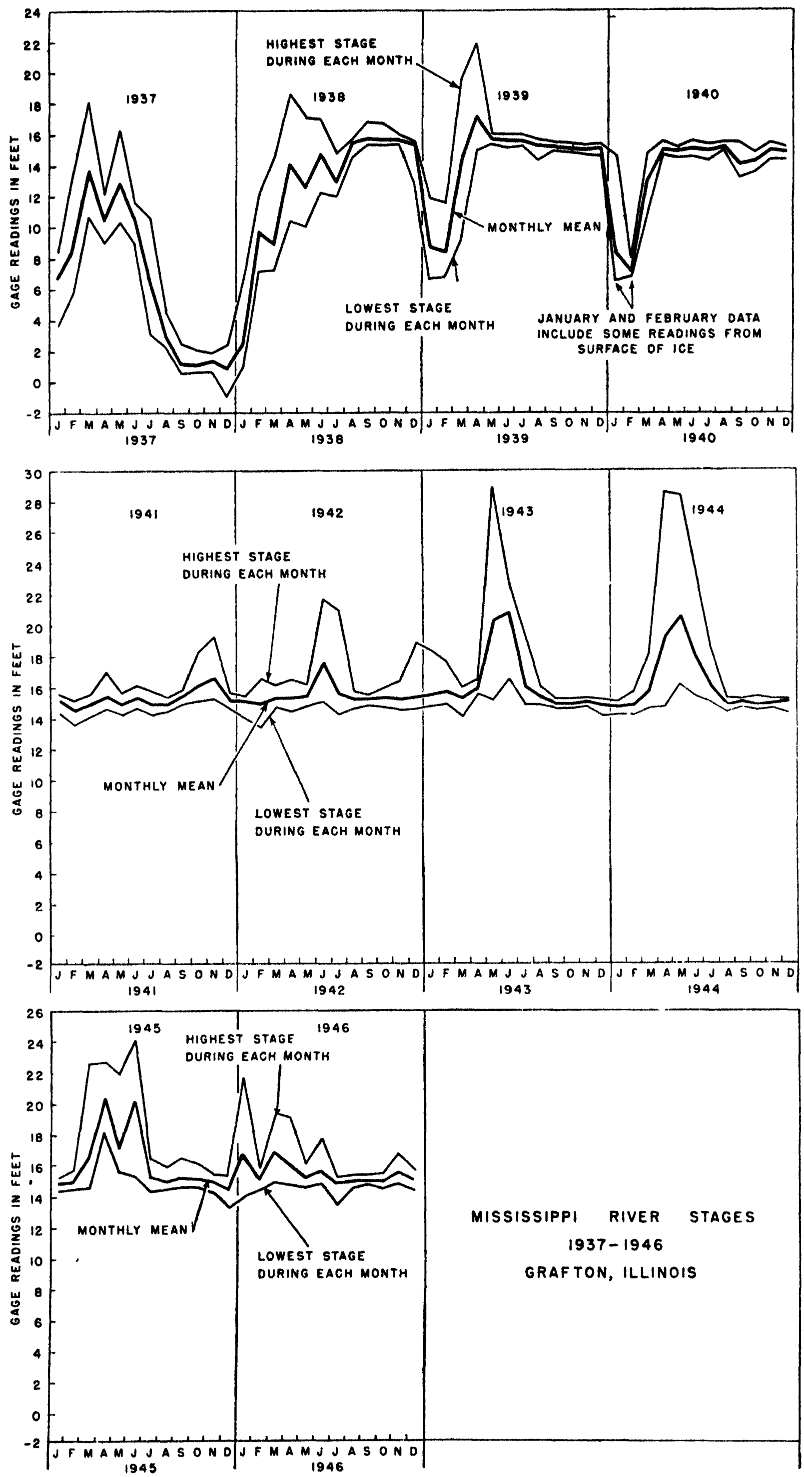


Fig. 5.—Mississippi River stages about 2 miles downstream from Calhoun County study area.

fluctuations in water level came at other times. With the exception of the three spring floods, the more pronounced changes came during the dormant season and presumably had only a minor effect on woody species. The peaks of the 1943 and 1944 floods occurred during cool weather before the growing season was fully under way, at least for trees.

TREE MORTALITY

Although it is universally known that most trees and shrubs die when subjected to permanent flooding, the rate of dying, by species, diameter classes, and depths flooded, has received little specific study, and is not well known. Green (1947) reported on the only other study on this subject known to the writer. His work, also in the upper Mississippi River valley, covered the period 1939–1944.

Table 2 indicates roughly the rate of dying in common upper Mississippi River valley trees and shrubs in the Calhoun County study area, and tables 3 and 4 show the effect of flooding on these species by diameter classes and water depths, respectively. Trees indicated in the "land" classification were on unflooded area at pool stage; trees in the "mud" classification were well above the original permanent water level but, subsequent to flooding, mainly along the new shore lines and other low areas of muddy nature; trees in the "water" classification were entirely on newly flooded land, except for willow and buttonbush. These two species, therefore, did not occur in the "land" sample, nor did boxelder, red mulberry, and several less important species in the "water" sample. The effect of flooding on trees under "water," "mud," and "land" conditions is discussed below.

Trees Standing in Water

Virtually all trees permanently flooded to a depth of 20 or more inches were dead by 1946, 8 years after the initial impoundment, fig. 6. Species varied considerably in rate of mortality, table 2. Only

Fig. 6.—Most trees and shrubs flooded to depths above the root collar died in 1 to 6 years. Shown above is a waterprivet, relatively resistant to flooding, that died during the fourth year when flooded 20 inches. The large tree is a persimmon, which died during the second year. A heavy mat of duckweed covered the water in this area. The writer, taking notes, October, 1941.

Table 2.—Rate of dying of trees in six study transects, Calhoun County, Illinois, 1938–1944. Permanent flooding of area was begun in June, 1938.

Species	Trees on Land						Trees in Mud						Trees in Water					
	Number of Trees Tagged, October, 1939	Per Cent of Trees Dead					Number of Trees Tagged, October, 1939	Per Cent of Trees Dead					Number of Trees Tagged, October, 1939	Per Cent of Trees Dead				
		June, 1940	October, 1940	June, 1941	October, 1942	October, 1944		June, 1940	October, 1940	June, 1941	October, 1942	October, 1944		June, 1940	October, 1940	June, 1941	October, 1942	October, 1944
Maple, silver	216	1.4	2.8	3.2	4.2	5.1	55	0.0	11.1	18.2	20.0	45.5	177	43.5	54.8	68.4	98.9	100.0
Elm, American	98	1.0	2.0	4.1	5.1	6.1	37	0.0	0.0	2.7	13.5	51.4	104	22.1	34.6	49.0	97.1	100.0
Ash, white	59	0.0	0.0	0.0	0.0	0.0	18	0.0	0.0	0.0	0.0	16.7	31	3.2	3.2	3.2	38.7	71.0*
Oak, pin	46	4.3	6.5	8.7	19.6	28.2	5	0.0	0.0	0.0	100.0	100.0	28	71.4	100.0	100.0	100.0	100.0
Pecan	46	0.0	0.0	0.0	0.0	0.0	2	0.0	0.0	0.0	0.0	100.0	26	23.0	42.4	61.5	88.5	100.0
Waterprivet	18	0.0	0.0	0.0	0.0	0.0	5	0.0	0.0	0.0	0.0	0.0	47	32.0	42.6	53.2	70.2	83.0†
Persimmon	27	3.7	3.7	3.7	3.7	3.7	5	0.0	0.0	0.0	0.0	80.0	35	22.9	42.9	48.6	100.0	100.0
Waterlocust	24	0.0	0.0	4.2	4.2	4.2	2	0.0	0.0	0.0	0.0	100.0	25	36.0	52.0	64.0	92.0	96.0
Hackberry	45	0.0	2.2	2.2	4.2	4.2	3	0.0	0.0	33.3	33.3	66.7	3	33.3	33.3	33.3	100.0	100.0
Hawthorn	17	11.7	11.7	11.7	11.7	11.7	4	0.0	0.0	0.0	75.0	75.0	16	56.2	81.3	81.3	100.0	100.0
Willow, black	0	—	—	—	—	—	0	—	—	—	—	—	23	13.0	17.4	21.4	39.1	43.5‡
Birch, river	4	0.0	0.0	0.0	0.0	0.0	2	0.0	0.0	0.0	0.0	0.0	17	76.5	94.0	94.0	100.0	100.0
Boxelder	20	0.0	0.0	0.0	0.0	0.0	0	—	—	—	—	—	0	—	—	—	—	—
Mulberry, red	15	0.0	0.0	0.0	0.0	0.0	0	—	—	—	—	—	0	—	—	—	—	—
Buttonbush	0	—	—	—	—	—	0	—	—	—	—	—	15	20.0	26.6	40.0	53.3	60.0**
Cottonwood	5	0.0	0.0	0.0	0.0	0.0	1	0.0	0.0	0.0	0.0	0.0	9	11.1	44.5	66.7	100.0	100.0
Holly	6	0.0	0.0	0.0	0.0	0.0	1	0.0	0.0	0.0	0.0	0.0	8	25.0	25.0	37.5	100.0	100.0
Oak, bur	3	0.0	0.0	0.0	0.0	0.0	0	—	—	—	—	—	5	20.0	60.0	100.0	100.0	100.0
Sycamore	6	0.0	0.0	0.0	0.0	0.0	0	—	—	—	—	—	0	—	—	—	—	—
Dogwood	2	0.0	0.0	0.0	0.0	0.0	0	—	—	—	—	—	0	—	—	—	—	—
Plum, American	1	0.0	0.0	0.0	0.0	0.0	0	—	—	—	—	—	0	—	—	—	—	—
Elm, slippery	1	0.0	0.0	0.0	0.0	0.0	0	—	—	—	—	—	0	—	—	—	—	—
Coffeetree	1	0.0	0.0	0.0	0.0	0.0	0	—	—	—	—	—	0	—	—	—	—	—
Redbud	1	0.0	0.0	0.0	0.0	0.0	0	—	—	—	—	—	0	—	—	—	—	—
Total	661	1.4	2.3	3.0	4.2	5.3	140	0.0	4.3	8.6	17.9	45.7	569	33.7	47.1	58.0	88.8	93.5

* Sample indicated that 93 per cent were dead in 1946
† Sample indicated that about 85 per cent were dead in 1946
‡ Sample indicated that 61 per cent were dead in 1946.
** No sample taken in 1946.

Fig. 7.—Diameter of tree or shrub had little effect on survival after flooding except in semiaquatic species and in reproduction sizes. In the area pictured above, all trees of 3 to 30 inches (larger trees in background) had succumbed by October, 1946, in 8 years of permanent flooding.

buttonbush, willow, and, to a less degree, waterprivet appeared to be adapted to conditions induced by impounded waters. Buttonbush did not succumb except where completely, or nearly, inundated. The few ash trees still living in October, 1946, were obviously dying.

Trees and shrubs of the various diameter classes showed little differentiation in survival ability after flooding except in the 2-inch class, table 3. In this class the difference was due to species (waterprivet and buttonbush, both semiaquatic) rather than to size, fig. 7. In general, healthy, vigorous trees of each species showed the greatest resistance to flooding, and the very small and the overmature classes of each species showed the least resistance.

Trees and shrubs still living and vigorous in 1944 were, in all cases, on the less deeply flooded areas; only waterprivet, buttonbush, and black-willow shrubs or trees still survived in water over 20 inches deep, table 4. More than half of the waterprivets and willows were dead by October, 1946. Before 1938, willows grew naturally in water or on the banks of sloughs and were flooded to greater depths than any other tree species; the depth averaged approximately 3 feet on the lower (northern) end of Calhoun Point. Had willows occurred in position to sustain all depths of inundation, a higher percentage of survival probably would have resulted. To all but semiaquatic species, permanent flooding to a depth of 20 inches or less above the root collar was fatal.

Trees Standing in Mud

Trees in mud, in comparison with trees standing in water, showed a more or less

Table 3.—Mortality of trees, by diameter classes, resulting from permanent flooding of river-bottom timber in six study transects, Calhoun County, Illinois, 1938–1944.*

Species	Diameter Class, Inches: 1–2			3–5			6–10			11–15			16–20			21–25			26 and over			Total		
	Number of Trees	Number Dead	Per Cent Dead	Number of Trees	Number Dead	Per Cent Dead	Number of Trees	Number Dead	Per Cent Dead	Number of Trees	Number Dead	Per Cent Dead	Number of Trees	Number Dead	Per Cent Dead	Number of Trees	Number Dead	Per Cent Dead	Number of Trees	Number Dead	Per Cent Dead	Number of Trees	Number Dead	Per Cent Dead
Maple, silver	0	—	—	21	21	100.0	43	43	100.0	40	40	100.0	38	38	100.0	17	17	100.0	18	18	100.0	177	177	100.0
Elm, American	0	—	—	9	9	100.0	55	55	100.0	29	29	100.0	6	6	100.0	0	—	—	5	5	100.0	104	104	100.0
Ash, white	2	2	100.0	8	5	62.5	8	7	87.5	5	4	80.0	3	1	33.3	3	1	33.3	2	2	100.0	31	22	71.0
Oak, pin	0	—	—	0	—	—	1	1	100.0	11	11	100.0	3	3	100.0	4	4	100.0	9	9	100.0	28	28	100.0
Pecan	0	—	—	0	—	—	3	3	100.0	15	15	100.0	6	6	100.0	1	1	100.0	1	1	100.0	26	26	100.0
Waterprivet	22	15	68.2	24	23	95.8	1	1	100.0	0	—	—	0	—	—	0	—	—	0	—	—	47	39	83.0
Persimmon	0	—	—	7	7	100.0	14	14	100.0	13	13	100.0	1	1	100.0	0	—	—	0	—	—	35	35	100.0
Waterlocust	0	—	—	5	5	100.0	3	3	100.0	10	9	90.0	4	4	100.0	3	3	100.0	0	—	—	25	24	96.0
Hackberry	0	—	—	2	2	100.0	0	—	—	1	1	100.0	0	—	—	0	—	—	0	—	—	3	3	100.0
Hawthorn	0	—	—	5	5	100.0	7	7	100.0	4	4	100.0	0	—	—	0	—	—	0	—	—	16	16	100.0
Willow, black	1	1	100.0	4	2	50.0	13	5	38.5	4	1	25.0	1	1	100.0	0	—	—	0	—	—	23	10	43.5
Birch, river	0	—	—	1	1	100.0	4	4	100.0	4	4	100.0	5	5	100.0	2	2	100.0	1	1	100.0	17	17	100.0
Buttonbush	14	8	57.1	1	1	100.0	0	—	—	0	—	—	0	—	—	0	—	—	0	—	—	15	9	60.0
Cottonwood	0	—	—	0	—	—	0	—	—	0	—	—	0	—	—	4	4	100.0	5	5	100.0	9	9	100.0
Holly	7	7	100.0	1	1	100.0	0	—	—	0	—	—	0	—	—	0	—	—	0	—	—	8	8	100.0
Oak, bur	0	—	—	0	—	—	3	3	100.0	1	1	100.0	1	1	100.0	0	—	—	0	—	—	5	5	100.0
Total	46	33	71.7	88	82	93.2	155	146	94.2	137	132	96.3	68	66	97.1	34	32	94.1	41	41	100.0	569	532	93.5

* See footnotes for table 2 regarding white ash, waterprivet, black willow, and buttonbush.

Table 4.—Mortality of trees, by depth flooded, resulting from permanent flooding of river-bottom timber in six study transects, Calhoun County, Illinois, 1938–1944.*

Species	1–10 Number of Trees	1–10 Number Dead	1–10 Per Cent Dead	11–20 Number of Trees	11–20 Number Dead	11–20 Per Cent Dead	21–30 Number of Trees	21–30 Number Dead	21–30 Per Cent Dead	31–40 Number of Trees	31–40 Number Dead	31–40 Per Cent Dead	41 and over Number of Trees	41 and over Number Dead	41 and over Per Cent Dead	Total Number of Trees	Total Number Dead	Total Per Cent Dead
Maple, silver	57	57	100.0	71	71	100.0	33	33	100.0	12	12	100.0	4	4	100.0	177	177	100.0
Elm, American	56	56	100.0	40	40	100.0	6	6	100.0	2	2	100.0	0	—	—	104	104	100.0
Ash, white	17	9	55.5	7	6	85.7	2	2	100.0	3	3	100.0	2	2	100.0	31	22	71.0
Oak, pin	15	15	100.0	7	7	100.0	6	6	100.0	0	—	—	0	—	—	28	28	100.0
Pecan	7	7	100.0	16	16	100.0	3	3	100.0	0	—	—	0	—	—	26	26	100.0
Waterprivet	6	2	33.3	12	10	83.3	7	6	85.7	11	10	90.9	11	11	100.0	47	39	83.0
Persimmon	13	13	100.0	16	16	100.0	2	2	100.0	4	4	100.0	0	—	—	35	35	100.0
Waterlocust	4	3	75.0	10	10	100.0	6	6	100.0	1	1	100.0	4	4	100.0	25	24	96.0
Hackberry	2	2	100.0	1	1	100.0	0	—	—	0	—	—	0	—	—	3	3	100.0
Hawthorn	5	5	100.0	6	6	100.0	3	3	100.0	2	2	100.0	0	—	—	16	16	100.0
Willow, black	5	0	0.0	7	1	14.3	2	1	50.0	3	2	66.7	6	6	100.0	23	10	43.5
Birch, river	5	5	100.0	6	6	100.0	4	4	100.0	0	—	—	2	2	100.0	17	17	100.0
Buttonbush	3	0	0.0	3	1	33.3	2	1	50.0	1	1	100.0	6	6	100.0	15	9	60.0
Cottonwood	4	4	100.0	4	4	100.0	1	1	100.0	0	—	—	0	—	—	9	9	100.0
Holly	6	6	100.0	2	2	100.0	0	—	—	0	—	—	0	—	—	8	8	100.0
Oak, bur	0	—	—	2	2	100.0	1	1	100.0	2	2	100.0	0	—	—	5	5	100.0
Total	205	185	90.2	210	199	94.8	78	75	96.2	41	39	95.1	35	35	100.0	569	532	93.5

* See footnotes for table 2 regarding white ash, waterprivet, black willow, and buttonbush.

parallel, but less severe, mortality rate, table 2. In the transects selected for study, the number of trees in mud was small; also, the ultimate effect of mud, after 8 years, was less obvious than that of water, since reactions in this medium were slower.

In view of the small area of mud in the transects, supplementary observations were made in October, 1944. The data obtained vary from those of the transect samples only in method and places of collection. As presented in table 5, the supplementary data represent a special effort to enlarge the mud sample, particularly for cottonwood, birch, hackberry, persimmon, pecan, buttonbush, and pin oak. They were collected from strips running parallel to mud flats rather than at right angles to them. These parallel strips were near transects 1, 6, and 7, and were 30 to 50 feet wide; trees were taken in order of occurrence, regardless of species, size, or condition. It is believed that this procedure eliminated the error of selectivity, and, since the two sets of data show similar trends, together they give added reliability to the conclusions.

Raising of the water table so as to turn low ridges into mud flats resulted in timber mortality at the end of 6 years that ranged from 50 per cent to nearly 100 per cent, except for such species as privet, white ash, river birch, and cottonwood. The species best able to tolerate change of this kind clearly are waterprivet and buttonbush, as would be expected. By 1946, it appeared likely that a higher percentage of trees of all species would die in time, and that the mud flats would support cattail *(Typha latifolia)* or other marsh plants, or grow up to willow, cottonwood, white ash, and perhaps other forest reproduction, fig. 20. Extensive invasion of cattail, and, in some cases, arrowhead or duckpotato *(Sagittaria* spp.), fig. 8, had occurred prior to the extreme floods of April and May, 1943 and 1944, which destroyed most of them. In 1946, these marsh plants were reappearing.

In a study of the influence of flooding in upper Mississippi River pools, Green (1947) noted few deleterious effects on timber growing on land higher than the contour 2 feet above normal pool level. In the present study, the "mud" sample lay lower than the 2-foot contour, being in fact where the water table lay at or very near the ground surface. Green noted the appearance of forest reproduction on cleared area between pool stage and the 2-foot contour. Similar observations were recorded many times during the present investigation.

Trees Standing on Land

Even for land not actually flooded the water table was raised approximately 3 feet as a result of closing the Alton Dam.

Table 5.—Mortality in various species of trees on mud sites in study area, Calhoun County, Illinois, October, 1944. Permanent flooding of area was begun in June, 1938.

Species	Sample (From Table 2)		Supplementary Observations	
	Number of Trees	Per Cent Dead	Number of Trees	Per Cent Dead
Maple, silver	55	45.5	48	45.8
Elm, American	37	51.4	62	54.8
Ash, white	18	16.7	30	16.7
Oak, pin	5	100.0	25	96.0
Pecan	2	100.0	20	85.0
Waterprivet	5	0.0	17	0.0
Persimmon	5	80.0	23	78.3
Waterlocust	2	100.0	0	—
Hackberry	3	66.7	11	81.8
Hawthorn	4	75.0	6	83.3
Birch, river	2	0.0	10	20.0
Buttonbush	0	—	18	0.0
Cottonwood	1	0.0	18	27.8
Holly	1	0.0	0	—
Total	140	45.7	288	49.3

Fig. 8.—Cattail, rice cutgrass, duckpotato, smartweed, and other marsh or moist-soil plants invading timberland where the water table had been raised to the soil surface Timber stand is dead or dying, October, 1941.

That timber stands were affected thereby was apparent, though not conspicuously so except in pin oak. This species, even on the unflooded land, suffered a mortality of 28.2 per cent by October, 1944, little more than 6 years after initial impoundment, and dying was noticeably progressive. Mortality in other common species was much lower, table 2. White ash, pecan, cottonwood, waterprivet, and several other species on unflooded land showed no loss as a result of the rise in the water table. Willow and buttonbush were not represented in the land sample.

By October, 1944, the two most numerous species on the area, silver maple and American elm, showed losses of 5.1 and 6.1 per cent, respectively, probably somewhat greater than natural mortality in stands where large poles and standards predominate. On land, the greatest loss in both maple and elm, as well as other species, was in the very large, overmature trees. The other common river-bottom species, persimmon, hackberry, and waterlocust, showed only slightly lower death rates than maple and elm. The death of two very large, old hawthorns, among 17 trees of this genus growing on land in the transects, is believed to have resulted from natural causes, rather than flooding, as other hawthorns growing outside of the transects were observed to be tolerant of the raised water table.

Discussion

Pin oak was easily the species most susceptible to injury by flooding, showing symptoms of dying as well as complete mortality before any other. Pin oak trees flooded in June, 1938, were clearly in a dying condition in September, 1939; by June, 1940, over 70 per cent had died, table 2. All were dead by October, 1940. In water, river birch indicated a slightly higher mortality rate than pin oak by June, 1940, but a somewhat slower dying rate thereafter. Pin oak trees in mud and on land sites with raised water levels died less rapidly than those in water, but all in mud succumbed before October, 1942, little more than 4 years after the original impoundment. A water table

raised to the ground level (trees in mud) was less injurious to river birch than to pin oak. Of the trees in water, hawthorn and silver maple, in June, 1940, were third and fourth, respectively, in rate of dying. The approximate number of years at which various species reached 100 per cent mortality is shown in table 6.

Fig. 9.—White ash was among the tree species most resistant to flooding. A few vigorous individuals, in less than 2 feet of water, threw trunk sprouts in 1946, during the ninth year of flooding. Two recently built duck blinds are shown in the center background.

Some pin oak trees died in 1 year, and other species showed high loss at least 1 year before the time of 100 per cent mortality. Most maples (98.9 per cent) and elms (97.1 per cent) were dead in little more than 4 years, table 2. Surviving white ash and waterlocust trees at the end of 6 years were so severely injured that few showed leaf in 1946. However, a few white ash trees showed small green trunk sprouts in October of that year. These were young trees flooded to a depth of less than 2 feet, fig. 9. Waterprivet, buttonbush, and willow, all semiaquatic, survived in varying percentages. Invariably, living trees and shrubs in each species were those subjected to the shallowest flooding depths, in all except semiaquatic species less than 2 feet.

In summary, it may be said that flooding, under the conditions described, resulted in the death of most trees within a 5- or 6-year period. Although the effect of the three flooding conditions listed in table 2 differed only in degree in most species, several species, notably white ash, river birch, and cottonwood, were not greatly affected by a raised water table or flood-induced mud. These three species appear to be more tolerant of increased soil moisture than pin oak, American elm, pecan, persimmon, and others.

It was noted with interest that several species bore fruit under flooded conditions. During the second year after flooding, individual trees or shrubs of persimmon, hawthorn, holly, locust, cottonwood, willow, hackberry, privet, and buttonbush bore appreciable crops; and trees of maple, elm, ash, river birch, and pecan produced small crops. During the third year, willow, waterlocust, and waterprivet produced sparse crops and buttonbush a normal crop. Several persimmon trees growing on a steep-banked slough (Chickahominy, fig. 2) and with root systems inundated only on the lower or stream side, produced well in 1944. These trees died subsequently. Some pin oaks matured acorns in 1938, after being flooded temporarily in June of that year. No acorns were noted on flooded pin oaks in 1939, but they were observed that year on flooded bur oaks. Pin oaks on the highest land sites bore good crops in 1940, 1942, and 1944, but light to medium crops in the intervening years.

Differential rates of dying in parts of the same tree were commonly noted. This condition occurred where trees grew on the shores of steep-banked sloughs, in such position that the root collars were flooded on the stream side, but lay above the post-flooding level on the land side. Pecan, fig. 10, showed this differential dying phenomenon most frequently, but the same condition was noticed also in elm, cottonwood, and maple. A score or more of partly dead trees were observed on the banks of Big Slough in October, 1946; it seemed probable that most of these would die in time.

The setting of adventitious roots, particularly in willow, white ash, and buttonbush, and to a lesser degree in silver

Table 6.—Approximate period of flooding, up to 3 feet, required to kill all trees of various species in six study transects, Calhoun County, Illinois.

Two Years, October, 1940	Three Years, October, 1941	Four Years, October, 1942	Five Years, October, 1943	Six Years, October, 1944	Seven Years, October, 1945	Eight Years, October, 1946
Pin oak	Bur oak	Hawthorn	Silver maple†		Waterlocust‡	White ash**
	Hackberry*	Cottonwood	American elm†			Buttonbush
	Persimmon*	Holly		Pecan		Waterprivet††
	River birch*					Black willow††

* Listed as probable; all trees nearly dead at time of June 1941 inspection; no check made in October, 1941.
† Listed as probable; no check made in October, 1943.
‡ Listed as probable; no check made in October, 1945.
** All trees virtually dead after 8 years; a few trees with small green sprouts on trunks in October, 1946.
†† Uncertain; some trees at edge of flooded area in shallow water still living.

Fig. 10.—Some pecans and other trees with root collar flooded on one side but above water level on the other side died first on the flooded side

maple, was' especially noticeable in 1939 and 1940. Such root growth was most pronounced near the new water line, but, in decreasing density, it extended down the trunk and thus for several inches below the water surface. This reaction of certain woody species to the stimulus of a raised water level is, of course, well known.

The effect of flooding on forest reproduction was similar to that in parent trees. An 8-acre clearing south of Sawmill Slough showed in 1938 a dense stand of seedlings, with some stump sprouts of elm, maple, and other species. In October, 1939, practically all of this reproduction except that of white ash and waterlocust showed evidence of dying; in October, 1940, all was dead except white ash in a foot or less of water. Even the 4- to 6-foot ash seedlings succumbed where flooding occurred to a depth exceeding 12 or 15 inches. Of all species represented, ash reproduction showed greatest tolerance to permanent flooding.

TREE FALL

Tree fall in the following discussion refers to the dropping of branches as well as to actual fall of the tree, wholly or in part, in flood-killed timber as a result of death, decay, and wind action.

Rate and Manner of Falling

Falling of water-killed trees was not particularly noticeable until 1941, 3 years after the initial flooding. Prior to this time scattered trees and large branches had crashed, but this early fall was principally among the numerous large, multi-branched and decadent silver maples and small, badly suppressed trees of all species. Many of the large maples were 4 feet or more in diameter and some of them probably would have fallen if flooding had not occurred, fig. 3. By October, 1944, falling was more or less advanced in all species, indicating, as would be expected, rapid decay in this low, humid locality, figs. 11 and 12. Falling data are summarized in table 7.

Fig. 11.—Silver maple wind-thrown in 1940, about 2 years after initial inundation of the Calhoun County study area. Photographed in October, 1940.

The manner of falling in dead trees was confined to two general patterns, determined by the presence or absence of durable heartwood. Among the species having durable heartwood, pin oak was outstanding. Although the first to succumb to flooding, pin oak was the last to fall after death. Bur oak showed rather similar characteristics. Oak branches, particularly the larger ones, were slow to fall, since they contained a considerable volume of heartwood. In oaks, the sapwood decayed and fell usually off both trunk and larger branches, leaving standing skeletons of heartwood. Five years or more were required for this degree of decay. Dead oaks with sound wood were usually uprooted by winds rather than broken off, although in oaks weakened by advanced heart rot the reverse was true. Waterlocust, except for the larger trees, many of which were decadent, possessed strong heartwood and stood well. Branches of locust trees tended to fall after a year or two. White ash, with only fairly durable heartwood, and often with advanced heart rot in the larger trees, was intermediate in ability to stand.

There is a long list of river-bottom trees known to have quick-rotting heartwood. Most numerous of these trees on the study area were silver maple, American elm, pecan, persimmon, sugar hackberry, cottonwood, river birch, and willow. Of these species persimmon and overmature maple trees fell first. Multi-branched, spreading trees of all species characteristically lost their branches, leaving low, stubby, and often hollow snags. Vigorous maple, hackberry, birch, and willow trees were somewhat slower in falling, and all fell at about the same rate. Among species having nondurable heartwood, elm, pecan, and cottonwood were most resistant to falling. Cottonwood was surprisingly durable; mature trees dying in 1942 and possibly earlier were cut for lumber in the fall of 1944. Such trees, while having decayed sapwood, usually showed sound, though often stained, heartwood; they had been vigorous in life; and many of them were 2 and some 3 or more feet in diameter, fig. 13.

Table 7.—Degree of falling in river-bottom timber on six study transects, October, 1944 and 1946, Calhoun County, Illinois.* Permanent flooding of area was begun in June, 1938.

Species	Number of Trees Dead	Degree of Falling†											
		Main Branches On		Main Branches Off		One-Fourth Down		One-Half Down		Three-Fourths Down		Down	
		1944	1946	1944	1946	1944	1946	1944	1946	1944	1946	1944	1946
Maple, silver	232	64	4	23	22	30	45	52	68	24	38	39	55
Elm, American	141	74	9	29	18	10	38	18	32	2	14	8	30
Ash, white	49	37	8	0	12	0	8	4	5	0	4	8	12
Oak, pin	33	14	9	8	10	3	5	4	4	2	3	2	2
Pecan	28	3	0	11	8	6	10	5	6	2	2	1	2
Waterprivet	52	20	0	0	4	3	8	12	13	1	8	16	19
Persimmon	40	3	0	3	0	2	3	7	8	7	9	18	20
Waterlocust	27	6	1	10	9	2	8	4	4	1	1	4	4
Hackberry	6	2	0	2	0	1	4	0	1	0	0	1	1
Hawthorn	20	8	0	2	0	1	5	5	7	0	2	4	6
Willow, black	23	0	0	0	0	0	0	7	4	2	1	14	18
Birch, river	19	0	0	0	0	1	2	12	12	2	0	4	5
Buttonbush	15	3	0	0	0	0	0	3	0	0	5?	9	10?
Cottonwood	10	1	0	3	0	3	2	0	3	1	1	2	4
Holly	9	4	0	0	0	0	2	0	0	0	0	5	7
Oak, bur	5	0	0	0	0	1	0	3	2	1	2	0	1
Total	709	225	31	105	83	63	140	136	169	45	90	135	196

* Water and mud sites combined, tagged sample only. See text for discussion of 1946 data.
† "One-Fourth," "One-Half," etc., refer in each case to that portion of trunk broken off.

It was characteristic of species having nondurable wood to break off at varying distances above the ground; in such species, standing heartwood skeletons did not long remain, as they did in the oaks. Persimmons particularly showed a tendency to snap cleanly, leaving stubs ranging from 1 to 20 feet high. Maples that had been sound and vigorous, and all other central-stemmed species in the nondurable group, first lost their branches and soon afterward broke off at some point one-fourth to one-half way down from the top of the main stem, fig. 14. Decadent trees in this group tended to break off at some point of weakness, such as a rotted branch stub.

Although falling was not common until 1941, 3 years after permanent flooding was begun, it was so advanced in October, 1944, that travel in many places was not possible in a light canoe. A number of channels cleared prior to flooding were blocked in scores of places by logs and debris. Many areas that were maple flats and shallow sloughs at the time of flooding had become, at the end of 6 years, so many acres of stubs, varied in height and standing in shallow water that was clogged by a maze of fallen tree tops and trunks, fig. 15.

By October, 1946, approximately 8 years after permanent flooding was begun, tree fall had obliterated transect markings to such an extent that these lines could be followed only with difficulty where they crossed flooded areas. It was often impossible to find the metal tags with which sample trees had been marked. Some of these tags were undoubtedly buried on the undersides of fallen trees, in a foot or more of mud; others, presumably, had dropped off the rapidly decaying trunks and were lost in the mud and water below. For this reason, the entries under 1946 in table 7 do not have as high a degree of accuracy as the data for other years. The writer is confident, however, that the trend indicated by the 1946 data is not misleading, since falling was obviously far more advanced in October, 1946, than at the time of the 1944 inspection.

Fate of Fallen Trees

Most of the falls on Calhoun Point were in water. Many tops and branches

landed on end, becoming deeply embedded in the soft mud bottom. Many tree trunks, even when they fell in water deep enough to float them, became waterlogged and sank. Trees falling in shallow water, cottonwood and willow, are constant sources of river driftwood. Clearing of the shore lines appears to be the most practical method of reducing the amount of driftwood which, in navigable streams, is

Fig. 12.—Same log as in fig. 11, October, 1946. Dying in 1939 and falling in 1940, this maple showed advanced decay and disintegration, to be expected of nondurable woods in low, humid localities in the temperate zone.

unless held up by other falls, settled in the mud. Thus, logs and tops tended to remain on or very near the site of fall, or, if dislodged, were soon caught against the thousands of trees and stubs that covered the area. Comparatively few of these logs reached the Illinois and Mississippi rivers from the interior of the Pere Marquette tract, even during the severe floods of 1943 and 1944.

Many green or flood-killed trees that have grown along the shores of navigable streams are uprooted and swept into the main channels. Flooded, uncleared islands in the Mississippi River, covered mostly by an appreciable nuisance or even a hazard to river shipping and also to commercial fishing.

That few logs from Calhoun Point reached the Mississippi River was due to the fact that, prior to flooding, an extensive and thorough clearing operation had been performed along the Illinois River shore line. Much of the Mississippi River shore line at this point is low bluff, somewhat higher than pool stage. For this reason little or no tree mortality occurred from the rise in water level, and no dead timber from this shore reached the river channel.

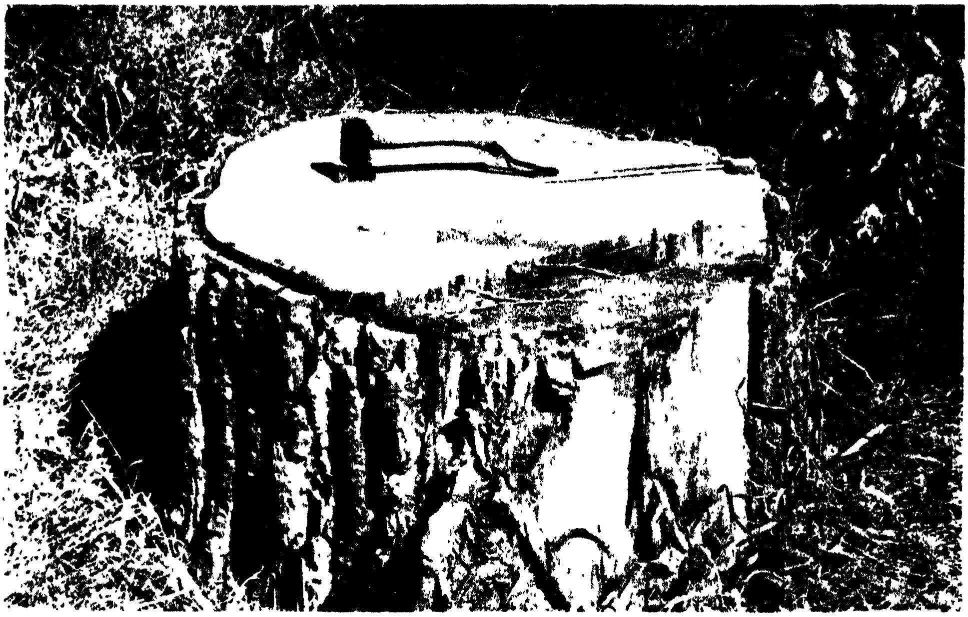


Fig. 13.—A 42-inch cottonwood flooded about 4 inches on the lower side in 1938. It died in 1942 and was cut for lumber in 1944. The heartwood was still sound but stained in October, 1946.

POST-FLOODING SUCCESSION

General, and for the most part incidental, observations on changes in plant and animal life subsequent to flooding were recorded during the investigation. Very profound changes are, of course, still in progress; this report is merely a summary of early succession phenomena.

Plants

The most conspicuous change in plant life was that of death in flooded timber. At the end of 8 years, most of the dead and fallen stand was in water less than 3 feet deep.

Conversion of much of this area, log-filled and snag-studded, to marsh was to be expected, and this transition had begun before 1946. Ecological development in the area following flooding may be ascribed largely to spread of plants already present and to introduction of seeds by water. As early as 1938, 2 years after excavation, borrow pits on the east end of the area supported vigorous stands of cattail *(Typha latifolia)*. By 1940, cattail stands had appeared in a scattered pattern on most of the water areas, as well as on wooded sites (timber dead) where the water table approached the ground surface, fig. 8. Stands of duckpotato *(Sagittaria* spp.) were particularly abundant along the lower end of Big Slough, where the channel had been deepened. Along the shore lines of both the Illinois and Mississippi rivers, rows of smartweed *(Polygonum* spp.) and cockspur or wild millet *(Echinochloa* spp.) appeared in both mixed and pure stands, undoubtedly due to the windrowing effect of wave action, fig. 16. Luxuriant growths of rice cutgrass *(Leersia oryzoides)* developed along the margins of many flooded areas in 1946, fig. 17.

Water in the sloughs and lakes, backwater in nature and without current except that induced by the rise and fall in pool levels, became progressively clearer toward the head of such bodies, even with the initial inundation in 1938. This condition permitted luxuriant growths of coontail or hornwort *(Ceratophyllum demersum)* and leafy pondweed *(Potamogeton foliosus)*, which became very noticeable in 1939 and reached their greatest development in

1942. Very heavy stands of sedges (*Carex* spp.) sprang up along some of the more open sloughs and shallow-water areas. The water supported a layer of duckweed (*Lemna*, *Wolffia*, and *Spirodela*), commonly 1 inch thick, figs. 6 and 18. Filamentous algae covered every submerged object, fig. 19.

Extreme flood conditions during the early growing seasons of 1943, 1944, and 1945 had a profound effect on submerged and most emergent vegetation. The smothering effect of muddy, silt-laden flood water severely decreased the stands; during the summer and fall of 1943 and 1944, only scattered growths appeared; by 1945, all the plants mentioned above except duckpotato virtually disappeared from the area, but many of them had reappeared by the fall of the following year. Moist-soil species, particularly rice cutgrass, appeared in dense stands in 1946, probably from seed deposited by flood waters.

Forest reproduction, principally willow and cottonwood, appeared along the shore lines of the Mississippi and Illinois rivers as early as 1939, particularly where clearing had been done. Growth was vigorous in 1940. These species also appeared along the shore lines of the shallower and more open sloughs. Seeding was of course by wind and water from numerous parent trees still present on surrounding unflooded land.

On certain wet "flats," notably northwest of Lower Royal Lake and along part of the Illinois River shore line, silver

Fig. 14.—A silver maple stand, October, 1946, 8 years after inundation, showing falling and break-off characteristic of species having nondurable heartwood.

Fig. 15.—Silver maple "flat," flooded in 1938; a maze of fallen debris in October, 1946

Fig. 16.—Stand of smartweed *(Polygonum* spp., chiefly *lapathifolium)* along the Illinois River on Calhoun Point, October, 1941. Seed presumably "windrowed" by wave action.

maple reproduction was abundant in October, 1944, reaching a density of four stems per square foot on small areas. White ash and American elm seedlings were common. Some pecan and pin oak reproduction was noted at various points. By October, 1946, practically all open, unflooded land supported a fair to full stand of river-bottom forest seedlings. Maple, elm, ash, willow, cottonwood, pin oak, and pecan reproduction was growing vigorously at this time; in some places it was as much as 10 or more feet high, fig. 20.

Mammals

Among mammals, muskrats *(Ondatra zibethicus zibethicus)* were most receptive to conditions brought about by permanent flooding of about one-fourth of Calhoun Point. In a complete coverage of the area in February, 1938, Frank C.

Fig. 17.—Rice cutgrass had attained luxuriant stands along the margins of flooded woodland in the study area by October, 1946.

Fig. 18.—Mat of duckweed an inch thick covered much of Royal Lake, Calhoun Point, October, 1941.

Fig. 19.—Filamentous algae grew in heavy mats over every submerged object, here revealed by a 16-inch drawdown, October, 1940.

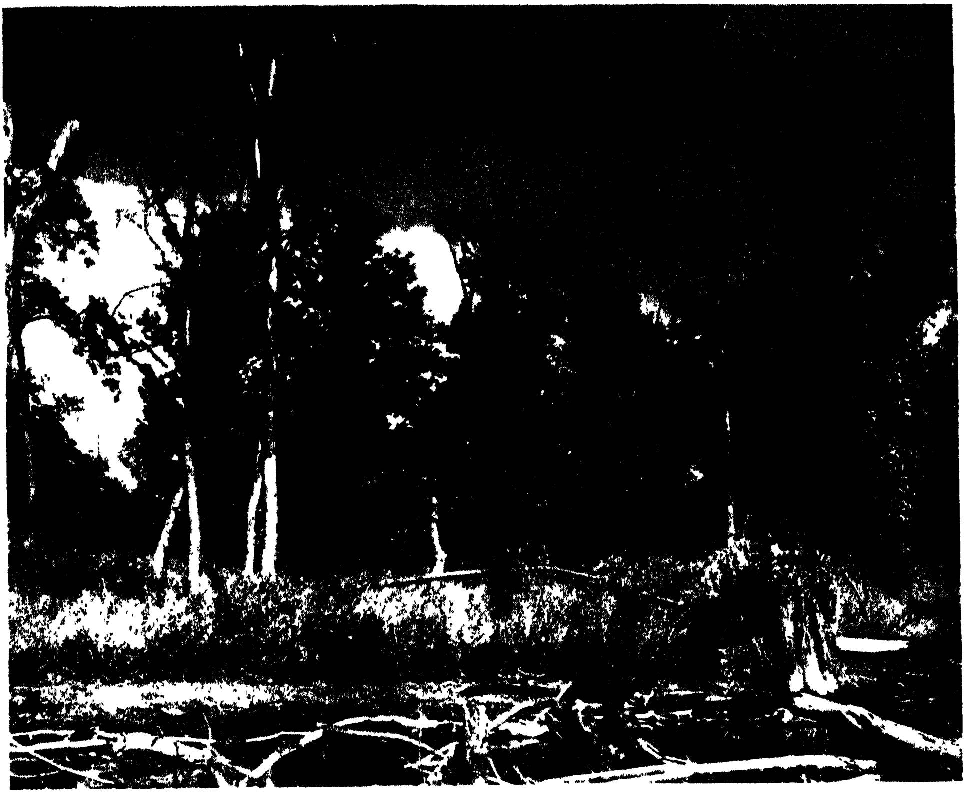


Fig. 20.—Willow, cottonwood, elm, and silver maple reproduction on mud flat following death of most of the original stand as a result of flooding that raised the permanent water level nearly to the ground surface. A luxuriant stand of rice cutgrass grew between the bare mud flat and the forest zone in October, 1946.

Bellrose, Jr., of the Illinois Natural History Survey (personal communication) found no sign indicating the presence of these animals. In April of that year, temporary closing of the Alton Dam flooded the borrow pits and sloughs along the rivers, and within a few days muskrats appeared. Muskrat signs were fairly common on June 2, 1938, and in places abundant in October of the same year. Strong evidence was found during the next 3 years that muskrats were increasing in numbers. By October, 1940, muskrat cuttings (chiefly of cattails and sedges), droppings, and burrows were noted in or near practically every slough on the area, fig. 21.

The steady increase in numbers of muskrats in the Calhoun Point study area (Yeager & Rennels 1943) is reflected by complete or partial counts of trappers' catches for five seasons, as follows:

Trapping Season	Muskrats Trapped
1938–39	50–75
1939–40	225
1940–41	260
1941–42	350*
1942–43	400*

* Number does not represent a complete count

The severe floods of 1943 and 1944 and a lesser flood of 1945 appeared to reduce the muskrat population appreciably, but muskrat signs were again common over much of the area in October, 1946. The destruction of cattail, coontail, and duckpotato by floods, as discussed under "Plants," probably accounted for seemingly increased use of sedges, smartweed rootstocks, and mussels late in 1944.

The effect of flooding on other fur animals of the study area is given in part by Yeager & Rennels (1943). Heavy trapping and loss of habitat, 1938–1940, resulted in decreased raccoon *(Procyon*

lotor) numbers during the next 2 or 3 years. However, this species, on Calhoun Point as elsewhere throughout its range, showed strong recovery by 1943. The raccoon population on the study area was high in 1944.

Opossums *(Didelphis virginiana virginiana)*, never heavily trapped or hunted floods reached their peaks during the young-rearing seasons. It is therefore not improbable that most of the animals, except those near the river bluffs, perished during the inundation. It should be remembered that, however well housed above the water level, any animal without food will find itself in dire straits before

Fig. 21.—Muskrat burrows under an old stump exposed by a drawdown of the water level of the Illinois River at Calhoun Point, October, 1940. The animals had attempted to plug entrances following exposure.

after about 1939 because of low fur prices, remained numerous on Calhoun Point until 1943, when floods of that year and 1944 apparently reduced their numbers to a very low point. Astonishing as it may seem, not a single opossum track was seen during an inspection trip over the area that lasted from October 13 to 18, 1944, although special efforts under excellent conditions were made to find such tracks. No reason other than flooding can be given for the scarcity of opossums. These animals are good climbers but not good swimmers, and they do not possess marked ability to take food from water. Since the entire point was flooded to a depth of several feet in both years, opossums there were separated from land by flood waters for as much as 3 miles. Moreover, the the end of a 2- or 3-week flood peak. Opossums showed some indication of coming back to Calhoun Point by October, 1946, but at that time they were far below their 1942 numbers.

Minks *(Mustela vison)*, animals that are highly adaptable and equally at home on land or in water, were affected by the Calhoun Point floods less than any other fur species. Signs indicating substantial populations were noted during every year of the study.

Both red foxes *(Vulpes fulva)* and gray foxes *(Urocyon cinereoargenteus cinereoargenteus)* were present on Calhoun Point previous to the initial flooding in 1938. Flooding reduced the habitable area for both species, and the peak floods of 1943 and 1944 undoubtedly evicted

them from the area. Abundant signs of foxes were never observed on the study area after 1944, though fox density on adjacent, but higher, areas remained at a very high point for several years.

Striped skunks *(Mephitis mephitis)* were more numerous in 1938 than at any other time of the study. Even in that year dens appeared to be confined to the highest ridge—the fallow field and the woods to the north of the field, both east of Big Slough. Flooding and the resultant 3-foot rise in the permanent water level undoubtedly made the area less suitable for this ground-denning species.

Woodchucks *(Marmota monax monax)* also were adversely affected by permanent flooding, although along the higher ridges their dens and other signs were fairly common in October of 2 years of this study, 1944 and 1946.

Calhoun Point has long been a favored locality for squirrel hunters. Until about 1940, gray squirrels *(Sciurus carolinensis)* predominated, as was attested by numerous hunters. Fox squirrels *(Sciurus niger rufiventer)*, until that time, were most common along the pin oak ridges bordering the large opening in the center of the area and along Big Slough and the west boundary, both territories adjoined by cultivated fields. With the death of large tracts of flooded timber and the resultant opening up of the stands, fox squirrels became the dominant species over practically the entire area. In October, 1944, the writer covered every part of the 4-square-mile tract and observed a total of 24 fox squirrels and 4 gray squirrels. Previously, the two species were more nearly equal in numbers.

Cottontail rabbits *(Sylvilagus floridanus)* were notably scarce on Calhoun Point, even before the 1943 and 1944 floods, which undoubtedly evicted them from the tract. They were more common along the inland boundaries of the area, and on adjacent farm land, a circumstance to be expected in view of the very low, wet nature of the greater part of Calhoun Point. Both food and nesting conditions on the study area were obviously less favorable than where waste grain, clovers, and other farm crops afforded abundant food, and higher sites provided safer nesting grounds.

Birds

Succession in bird life on this tract of flooded bottomland is indicated here only from general observations. Aquatic and marsh species, common before 1938, had become more numerous by 1944. Some indication of the increase is reflected in table 8, the data for which were taken from one 7-mile boat or canoe trip in each of 4 years on Big Slough, Royal Lake, Chickahominy Slough, and the Illinois River. The same route was followed at each observation. The general validity of the data in table 8 is strengthened by a number of other trips over the tract that yielded similar information.

Calhoun Point has been subjected to heavy duck hunting since 1938. One hun-

Table 8.—Numbers of birds observed on a 7-mile water trip through Pere Marquette study area in each of 4 years.

SPECIES	NUMBER OF INDIVIDUALS*			
	August 16, 1938	August 6, 1941	October 15, 1944	October 3, 1946
Wood duck	16	100	116	62
Black-crowned night heron	11	50	42	39
Yellow-crowned night heron	0	2	0	0
Great blue heron	6	10	22	19
American egret	6	68	40	31
Green heron	13	40	24	26
American bittern	1	2	0	3
Red-wing blackbird	10	56	40	24
Woodpeckers †	7	36	52	114

* All figures over 10 ending in "0" are estimates, believed to be conservative.
† Red-headed, pileated, flicker, downy, hairy, and red-bellied

dred or more blinds scattered through the 4-square-mile area resulted in widespread shooting almost daily during each hunting season. Because waterfowl were thus discouraged during the fall in their attempts to use the new marsh and flooded woodland, evaluation of the area for waterfowl purposes has been complicated. However, the tract became potentially more attractive to dabbling ducks in its flooded state than it was formerly, because of the larger shallow water area and the development of rice cutgrass, fig. 17, smartweed, fig. 16, wild millet, and other aquatic and moist-soil plants that furnish food for ducks.

Wood ducks *(Aix sponsa)* are the only wild waterfowl that nested in the area. Yearly observations by Frank C. Bellrose, Jr., and other members of the Natural History Survey staff indicate a severalfold increase in breeding and summer populations of these birds since 1938, apparently because of the greater area of attractive habitat. Nesting sites in the hundreds of hollow snags and trees are ample; and quiet, duckweed-covered waters in the flooded timberlands are probably ideal as rearing grounds. There was some evidence in 1946 of decreasing attractiveness of the area to wood ducks as a result of the opening up of flooded woodland and the trend toward the marsh stage of succession.

There was abundant evidence during much of the study period of a general increase in number of herons on the area. After 1941, a score or more of these birds could often be counted at a single stand, and, by including all of the concentration areas on the point, 500 to 700 herons could easily have been recorded in a day's time. On August 6, 1941, Harry G. Anderson, an ornithologist associated with the Natural History Survey, and the writer counted 200 American egrets *(Casmerodius albus egretta)*, 12 snowy egrets *(Egretta thula thula)*, and 40 great blue herons *(Ardea herodias herodias)* on one 20-acre bay. None of these birds is included in table 8. In June, 1941, four green heron *(Butorides virescens)* rookeries, averaging 20 nests each, were found in the course of routine work. Systematic coverage of the tract would probably have disclosed others. The 600 or more acres of shallow water, abounding in minnows, small fish, frogs, crayfish, and other food, afforded excellent foraging grounds for all species of wading birds present.

With the appearance of marsh, breeding populations of red-wing blackbirds *(Agelaius phoeniceus phoeniceus)* became established in 1938. On May 15, 1942, Harry G. Anderson and the writer counted 22 red-wing nests in less than one-half acre of cattail marsh in Sawmill Slough, north of Coon Lake. This was near the middle of the area; other red-wing colonies were found in the various cattail stands along the Illinois River, Big Slough, and other places. The 10 red-wings noted on August 6, 1938, table 8, were in the vicinity of a cattail marsh at the mouth of Chickahominy Slough.

Highly suitable nesting and food conditions for woodpeckers were provided by the thousands of dead trees, in every condition of decay, on Calhoun Point. An increase of woodpeckers on the area was noticeable as early as October, 1939, following the death of numerous maple and other trees. As listed in table 8, at least six species were observed, of which the red-headed woodpecker *(Melanerpes erythrocephalus)* was most common. Next in numerical abundance was probably the red-bellied woodpecker *(Centurus carolinus)*; the flicker *(Colaptes auratus luteus)* was third. An unusual number of pileated woodpeckers *(Ceophloeus pileatus abieticola)* were present, the writer observing 13 on the morning of October 14, 1944. At least six were in one scattered flock. Downy *(Dryobates pubescens)* and hairy woodpeckers *(D. villosus)* were other species recorded.

No attempt was made to determine the effect of flooding on perching birds. Such conspicuous forms as the prothonotary warbler *(Protonotaria citrea)* and American redstart *(Septophaga ruticilla)* were abundant on the area in years covered by this report. Harry G. Anderson and the writer recorded 45 of the former and 30 of the latter on May 15, 1942. A total of 66 species of birds were listed on that date, but it is certain that many of these were migrants. General evidence indicates that the prothonotary warbler, at least, increased over the population present on the area is 1938.

Starlings *(Sturnus vulgaris vulgaris)* were observed in considerable numbers on the area in October, 1946.

SUMMARY

1. Timber killed by impoundment of water for power development, channel improvement, flood control, and other purposes represents a problem of growing importance throughout the United States.

2. The effect of water impoundment on timber was studied over an 8-year period, 1939–1946, at the junction of the Mississippi and Illinois rivers, where sizable tracts of river-bottom timber were killed by the Alton Dam impoundment, first pooled in 1938.

3. The study area, Calhoun Point, consisted of 2,200 acres of river-bottom forest, sloughs, lakes, and small marshes. About 600 acres of this tract were flooded permanently by the Alton Dam, which raised the average summer water stage about 3 feet. This rise in level reduced the highest elevation on Calhoun Point from 10 to 7 feet above the average summer water surface.

4. Timber stands on the study area were all-age, river-bottom hardwoods characteristic of the upper Mississippi River valley. Silver maple was easily the dominant species; American elm, white ash, pin oak, pecan, river birch, cottonwood, black willow, persimmon, hackberry, and waterlocust were other common species. Important shrubs were buttonbush, waterprivet, and deciduous holly.

5. The effects of flooding were studied on sample areas, consisting of six 50-foot transects, aggregating 3.5 miles in length. These transects crossed all representative timber types on Calhoun Point. Individual trees in the sample were identified by numbered metal tags attached with galvanized nails at breast height. Records involving species, d.b.h., crown class, general vigor, depth flooded, and year of death were taken at intervals. A total of six inspections, in addition to the one at time of tagging, and numerous visits at other seasons, supplied the data for this report.

6. River stages, 1937–1946, at Grafton, Illinois, less than 2 miles downstream from the area, were studied in relation to the rate of dying in tree species and succession in aquatic vegetation.

7. The effect of flooding on timber was studied under three categories: (1) timber actually flooded; (2) timber on sites where the water table had been raised to the ground surface; and (3) timber on unflooded land, where the average summer water table had been raised approximately 3 feet.

8. Eight years of actual flooding of timber areas resulted in practically complete tree mortality. In most tree species, flooding to a depth sufficient to cover the root collar, less than 20 inches, was fatal. Rate of dying showed wide variation by species. Pin oak was most susceptible to injury from flooding, all individuals of this species dying before or during the third year. White ash was most resistant, a few individuals giving rise to trunk sprouts 8 years after inundation. Mortality in most other tree species was 100 per cent in 6 years. Waterlocust showed a mortality of 96.0 per cent and black willow 43.5 per cent in 6 years; a few trees of these species were still alive 8 years after impoundment. All bur oak trees were dead 3 years after permanent flooding was begun; all persimmon, hackberry, hawthorn, river birch, and cottonwood were dead in little more than 4 years. Most silver maple was dead in about 4 years; all silver maple, American elm, and pecan were dead in about 6 years.

9. The three shrub (or small tree) species represented in the water sample likewise varied in tolerance to flooding. Deciduous holly showed 100 per cent mortality in about 4 years. Waterprivet, in October, 1946, more than 8 years after flooding, showed 85 per cent mortality; surviving individuals were in less than 2 feet of water. It appeared in 1946 that some of these would live. Buttonbush was definitely the most tolerant species sampled, this shrub showing a survival of 40 per cent or more except when deeply submerged.

10. The diameter of trees and shrubs subjected to flooding had little influence on their death rate. An apparent difference in the 2-inch class was due to species rather than to size. In general, within each species, healthy, vigorous trees showed the greatest resistance to flooding, and the

very small class (other than in semiaquatic species) and the overmature class showed the least resistance. The depth flooded (short of submersion) likewise appeared to make little difference, provided the root collar was covered. A depth of less than 20 inches was sufficient to cover the root collar of all species involved.

11. The harmful effect of a raised water table was clearly discernible, particularly where mud conditions were created, but, for each species, tree mortality was less severe in mud than in water. To mud, as to water conditions, pin oak was very susceptible and white ash very resistant; semiaquatic shrubs like waterprivet showed no mortality in mud.

12. On land above the mud level, but subjected to a 3-foot rise in the water table, only pin oak showed conspicuous reaction. Here, at the end of approximately 6 years, mortality among trees of this species had reached 28.2 per cent and was noticeably progressive. Losses in elm and maple were much lower, and white ash, pecan, cottonwood, and several other trees and shrubs apparently were unaffected by the increased water level.

13. Several tree species bore fruit under flooded conditions. This occurrence was most pronounced during the first 2 years. Only willow, waterlocust, waterprivet, and buttonbush produced fruit during the third year subsequent to inundation.

14. Trees with root systems flooded only on one side showed differential dying rates in parts of the same tree, the side inundated being nearly always the first to die.

15. Willow, white ash, and buttonbush showed marked ability to set adventitious roots during the first 2 or 3 years of flooding. Silver maple showed this ability to a lower degree.

16. The effect of flooding on forest reproduction was similar to that on parent trees. White ash reproduction showed by far the greatest tolerance to flood conditions.

17. Falling of dead timber became noticeable 3 years after flooding; it was advanced 6 years afterward, and extremely pronounced 8 years afterward. Pin oak showed greatest resistance to trunk fall; other species, without durable heartwood, snapped off at varying distances along the trunk.

18. Dead timber falling on the study area became waterlogged or deeply embedded in mud. Few falls reached the Mississippi and Illinois rivers to offer hazards to shipping and commercial fishing.

19. By 1946, conversion to marsh of the flooded bottomland, then a jumble of fallen logs and debris lying in mud and shallow water, had begun. Cattail, duckpotato, and various sedges were the most common marsh invaders; smartweed, wild millet, and rice cutgrass held a similar position on moist soil.

20. Extremely heavy growths of coontail and leafy pondweed, often covered in the fall by a mat of duckweed, appeared in the clear-water sloughs and lakes during the first 4 years of flooding.

21. Floods, several feet above normal pool stage in 1943, 1944, and 1945, destroyed practically all submerged and emergent aquatic vegetation, but, by the fall of 1946 several species showed evidence of recovery.

22. Reproduction of river-bottom tree species was common in 1944, and, in 1946, seedlings of maple, elm, ash, willow, cottonwood, pin oak, and pecan were growing vigorously.

23. Among mammals, muskrats showed great adaptability to conditions induced by flooding. The severe floods of 1943 and 1944, and a lesser flood in 1945, apparently depleted their numbers, but there was evidence of recovery by October, 1946. Opossums and cottontail rabbits were apparently evicted from the area by the series of high waters.

24. Raccoons and minks, with some fluctuations in populations, remained common to abundant in the area throughout the period of study.

25. Land mammals, such as woodchucks, skunks, and foxes, found less and poorer habitat on the area after flooding in 1938 than previously. The 3-foot rise in the water table undoubtedly limited the area suitable for ground dens on this low flood plain.

26. Flooding improved the Calhoun Point habitat for wood ducks, herons, and woodpeckers, and was attended by noticeable increases in the populations of these three groups. The increase was perhaps

most conspicuous in woodpeckers, for which the thousands of dead and dying trees provided unlimited food and nesting sites. The development of cattail marsh was accompanied by increases in the number of nesting red-wing blackbirds. Considerable numbers of starlings were observed on the area in 1946.

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Canada Geese of the Mississippi Flyway

With Special Reference to an Illinois Flock

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FOREWORD

OF all of the geese inhabiting North America, the Canada goose stands at or near the top of the list in general recognition, and as a game bird. So well known is it that the mention of wild goose brings to the average person a mental picture of the great gray-bodied, black-necked, white-jowled "honker." Francis Kortright, in his *The Ducks, Geese and Swans of North America* says, "Sagacity, wariness, strength and fidelity are characteristics of the Canada Goose which, collectively, are possessed in the same degree by no other bird." The cold, calculating, investigative, scientific eye may occasionally cast doubt on the completeness with which some of these traits permeate the whole population (as will be noted in this report). One can, if he searches diligently, find a thriftless Scotchman.

Wide distribution, great size, and habits conspicuous to the ear and eye have all assisted in making the Canada goose a well-known bird; but most of the knowledge concerning it has been general and superficial. During some time in the year this goose may be seen from one coast to the other and from northern Canada to the Gulf of Mexico. To the average person this wide distribution might mean that the elimination of the species from any of its areas of habitation would be difficult. But every field biologist is familiar with the so-called "flyway concept" that has developed in the past few decades. This concept, backed by a large quantity of band-recovery data and general observation, is that the whole population of a migratory species may be divided into subpopulations, each having rather definite nesting and wintering areas and routes of movement, with a minimum of mixing among these subpopulation groupings.

On the basis of this thinking, the study of a migratory species breaks down into a number of geographic units, and the success or failure of one flyway population may affect but little the populations of other flyways.

This is the problem that faced those interested in the geese wintering in Illinois. From nesting grounds on the west side of James Bay in Canada, one segment of the Canade goose population moved south and west, and in recent years wintered to a very large extent at the Horseshoe Lake Game Refuge in Alexander County, Illinois. About half of the population of geese in the Mississippi flyway concentrated in a small area where excessive hunting could conceivably have affected numbers and hunting successes in a very large area both inside and outside the state. The object of the study reported herein was to ascertain the health of the Horseshoe Lake population, and this study required a broad attack both as related to the subject matter investigated and the geography involved.

Both of the authors have been far afield in this study. Mr. Smith, as Flyway Biologist for the United States Fish and Wildlife Service, has had an opportunity allowed to but a very few to observe this and other Canada goose populations. Mr. Hanson spent several years at Horseshoe Lake and parts of two summers in the James Bay nesting area

The section titled "Population Survival" represents an attempt to analyze a difficult problem with data difficult to obtain in quantity. The data available have been explored by Mr. Hanson, and certain conclusions reached. These conclusions, it is realized, may vary somewhat from the true picture, but it is felt that their inclusion is worth while as a stimulus to a fuller investigation of this problem even if there were no other values accruing.

A study such as the following must of necessity have authors. It is obvious, however, that an investigation of this magnitude is the result of the authors' efforts plus assistance from many people in numerous ways. To all who helped in any way we are deeply grateful.

HARLOW B. MILLS, *Chief*
Illinois Natural History Survey

CONTENTS

Evening flight of Canada geese at Horseshoe Lake.

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HAROLD C. HANSON
ROBERT H. SMITH*

HORSESHOE LAKE, formed from an ancient oxbow of the Mississippi River, lies in Alexander County, Illinois, at the southwest tip of the state, fig. 1. An area, totaling 3,489.77 acres, that includes the lake and the island it surrounds, was purchased by the Illinois State Department of Conservation in 1927 for use as a wildlife refuge. Subsequent purchases in 1941, 1945, and 1946 added about 220 acres to the area, now known as the Horseshoe Lake Game Refuge.

That the plan of use for the Horseshoe Lake area was eminently successful from the standpoint of attracting wildlife soon became evident. Flocks of Canada geese that previously had wintered along the Mississippi River in the region of southern Illinois left their traditional wintering grounds for the food supply and the rest lake provided by the refuge. In recent years, for varying periods during the autumn and winter, the Horseshoe Lake Game Refuge and the countryside immediately around it have contained approximately 50 per cent of the Canada goose population wintering in the entire Mississippi River valley.

Along with the increase in numbers of Canada geese at Horseshoe Lake there were two developments of primary importance: a tremendous increase in shooting pressure on the flock and an alteration in the behavior of the geese. Once as wary as any waterfowl population in the Mississippi River valley, the goose flock using Horseshoe Lake gradually lost most of its fear of man and gunfire while near the refuge. The obvious result of the greatly increased shooting pressure and the loss of normal wariness was a tremendous increase in the kill.

Large annual kills made at Horseshoe Lake, beginning in 1939, focused the attention of wildlife administrators on the need for a long-term management program in that area. In recognition of this need, the Natural History Survey Division of the Illinois State Department of Registration and Education instituted the research program on which the present report is based. When it became evident that the Horseshoe Lake goose problem was not only of local importance, but national and international in scope, the United States Fish and Wildlife Service initiated a program of investigations to cover the entire range of the Canada goose population wintering in the Mississippi River valley; these investigations extended from the James Bay region of Canada to the coastal marshes of Louisiana.

ACKNOWLEDGMENTS

For the generous co-operation on the research project at Horseshoe Lake by the Illinois Department of Conservation, the agency which operates and maintains the refuge, special appreciation is due officials or employees of the Department active during the period of field work:

* Flyway Biologist, United States Fish and Wildlife Service.

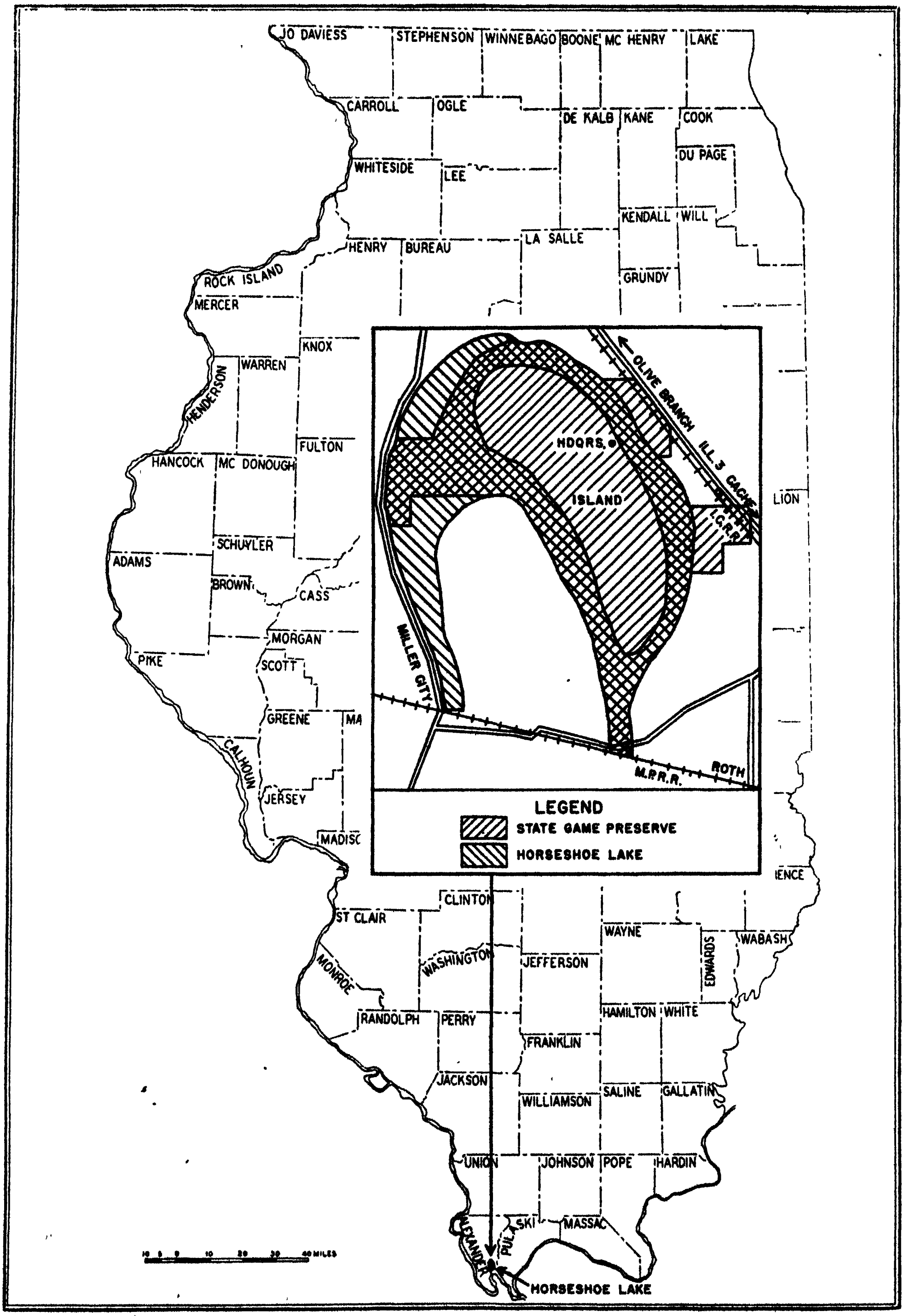

Fig. 1.—Map showing the boundaries and location of the Horseshoe Lake Game Refuge, 1946. The refuge area totaled about 3,700 acres at the end of that year. The original purchase, in 1927, involved about 3,500 acres.

Livingston E. Osborne, Director; Lewis E. Martin, Harold L. Gray, and Joe B. Davidson, members of the administrative staff; and Vernal Nave, C. E. Laughery, and Kenneth Long, refuge managers. The inception of the Canada goose study at Horseshoe Lake was in no small measure due to Paul S. Smith, formerly Chief Conservation Officer, Illinois Department of Conservation, and later Game Management Agent of the United States Fish and Wildlife Service. He was one of the first to recognize the serious consequences of the high Canada goose kills in southern Illinois and to awaken others to its dangers. The valuable co-operation given the research program by Smith was continued by his successor, Vernon C. Conover.

For their official helpfulness and personal interest in the research program, we are indebted to the late Dr. Theodore H. Frison, formerly Chief, to Dr. Leo R. Tehon, formerly Acting Chief, and to Dr. Harlow B. Mills, present Chief, of the Illinois Natural History Survey; to Dr. Clarence Cottam, Fredrick C. Lincoln, Jesse F. Thompson, Leo Couch, Dr. Gustav A. Swanson, and Richard Griffith, all of them during the period of field work with the United States Fish and Wildlife Service; to Dr. Harrison F. Lewis and T. S. Hennessey of the Dominion Wildlife Service, Canada Department of Mines and Resources; and to Dr. T. J. Orford of the Indian Affairs Branch, Canada Department of Mines and Resources.

Manly Miner, President of the Jack Miner Migratory Bird Foundation, Inc., acting in behalf of the Miner family and the Miner Foundation, was most helpful during the course of this study. For permission of the Miner family to compile and analyze the Miner goose-banding records, we are deeply appreciative.

The senior author was privileged to undertake field studies in the James Bay area in 1946 and 1947 under the auspices of the Arctic Institute of North America. For helpfulness in connection with this activity we wish to thank Dr. A. L. Washburn, Executive Director of the Institute.

In 1947, Ducks Unlimited provided the senior author with funds for an aerial reconnaissance of the breeding grounds of the Canada goose in northern Ontario and northeastern Manitoba. Appreciation is due for the support given this program by L. H. Barkhausen, B. W. Cartwright, and Arthur Bartley. Paul Queneau of Westport, Connecticut, rendered valuable assistance during these flights by operating one of the aerial cameras used and keeping a personal flight log of his observations.

We are grateful to Father John M. Cooper of the Catholic University of America for permission to quote from his unpublished report on tribal and family hunting grounds in the James Bay area and to reproduce a portion of his accompanying map, fig. 9. This report, on file in the Indian Affairs Branch, Canada Department of Mines and Resources, was made available to us through the courtesy of T. R. L. MacInnes.

Employees of the Hudson's Bay Company and other residents of the James Bay area have shown us many courtesies and contributed information. We are indebted to William B. Anderson, W. J. Cobb, Mathew Cowan, R. M. Duncan, William Faries, C. C. Forman, William Glennie, Patrick Houston, Wesley Houston, A. H. Michell, Father Leopold Morin, Thomas Rettalack, Norman Ross, Arthur Sullivan, and the late James Watt and Mrs. Watt. The above people, as well as the following, have zealously reported bands in past years: J. W. Anderson, Bishop Henri Belleau, Father Bilodeau, George S. Cotter, H. Gibbs, the Rev. Arnold C. Herbert, Brother Gerard Lavoie, the Rev. D. A. MacLachlan, Norman Mathew, L. G. Maver, P. A. C. Nichols, E. H. Riddell, the Rev. H. A. Turner, the Rev. J. H. Turner, J. B. Tyrer, and Harold Udgarden.

For information on the wintering grounds and kills of Canada geese in various states we are indebted as follows: for Michigan, Herbert J. Miller and Dr. Miles D. Pirnie; for Wisconsin, Therman Deerwester and F. R. Zimmerman; for Minnesota, Frank D. Blair; for Indiana, William B. Barnes; for Iowa, Bruce F. Stiles; for Missouri, M. O. Steen. Data for other states have been gathered largely by the authors, but Frank C. Bellrose of the Illinois Natural History Survey has furnished us with the information on Canada goose concentrations in the Illinois River valley.

From 1940 through 1943, staff members of the Illinois Natural History Survey carried out studies of a captive Canada goose flock on the Bright Land Farm near Barrington, Illinois, a program supported by the late A. L. Eustice and Mrs. Eustice, aided by Carleton A. Beckhart.

Cecil S. Williams, Dr. Elizabeth Brown Chase, Arthur S. Hawkins, and Dr. Gustav A. Swanson have read parts of the manuscript and given much helpful criticism. Dr. Chase and H. W. Bean have reviewed the statistical data. Arlone Hanson has contributed much valuable assistance in the field and in the office.

MATERIALS AND METHODS

This Canada goose study is based on data from three primary sources: data collected at Horseshoe Lake, Alexander County, Illinois; surveys by the authors on the distribution, habitat, and behavior of the population elsewhere in the Mississippi flyway; and banding records of the Jack Miner Bird Sanctuary, Kingsville, Ontario. Data from other sources have been used as indicated in the text.

Data From Horseshoe Lake

Most of the data relating to Canada geese of the Horseshoe Lake Game Refuge, prior to 1940, were obtained by Paul S. Smith when he was federal Game Management Agent. In 1940 and 1941, Arthur S. Hawkins, then Game Technician of the Illinois Natural History Survey, collaborated with Smith on an investigation of conditions at and near Horseshoe Lake. The first successful trap used at Horseshoe Lake was designed and constructed by John M. Anderson and Jacob H. Lemm of the Natural History Survey and in February, 1941, the first bandings of geese in the area were made by Hawkins, who recorded the sex and age classes of birds banded. In January and February, 1942, and in the winter of 1942–43, Dr. William H. Elder continued the trapping program begun by Hawkins. From the autumn of 1943 to the spring of 1947, the senior author was responsible for the research program at Horseshoe Lake.

In the studies at Horseshoe Lake, particular emphasis was given to trapping and banding (Hanson 1949*c*), often the only techniques whereby such vital statistics as average longevity and rate of population turnover can be obtained. These study techniques yielded data on sex and age composition of the flock, and, in connection with bag inspection, on the differential vulnerability of the sex and age classes. Sex and age criteria, flock habits and flock organization, crippling losses, and, as time permitted, diseases and parasites of Canada geese were also studied. The total numbers of Canada geese trapped and banded at Horseshoe Lake by the Illinois Natural History Survey are given in table 1.

Data From Jack Miner Sanctuary

On a number of occasions, members of the Illinois Natural History Survey staff

Table 1.—Number of Canada geese trapped at Horseshoe Lake, Alexander County, Illinois, by Illinois Natural History Survey personnel, during the fall and winter seasons of 1940–41 through 1946–47.

Season of Trapping	Geese Banded	Returns Retrapped*	Total Individuals	Repeats and Returns Retrapped*	Total Annual Catch
1940–41	315	0	315	11	326
1941–42	402	6	408	24	432
1942–43	1,036	18	1,054	147	1,201
1943–44	2,329	133	2,462	2,139	4,601
1944–45	853	248	1,101	1,567	2,668
1945–46	310	231	541	543	1,084
1946–47	502	215	717	289	1,006
Total	*5,747*	*851*	*6,598*	*4,720*	*11,318*

*A *return* is a goose trapped and banded at Horseshoe Lake that is retrapped at Horseshoe Lake in any year following the year of banding. A *repeat* is a goose trapped and banded at Horseshoe Lake that is retrapped at Horseshoe Lake in the year of banding, or a return that is retrapped more than once in any year.

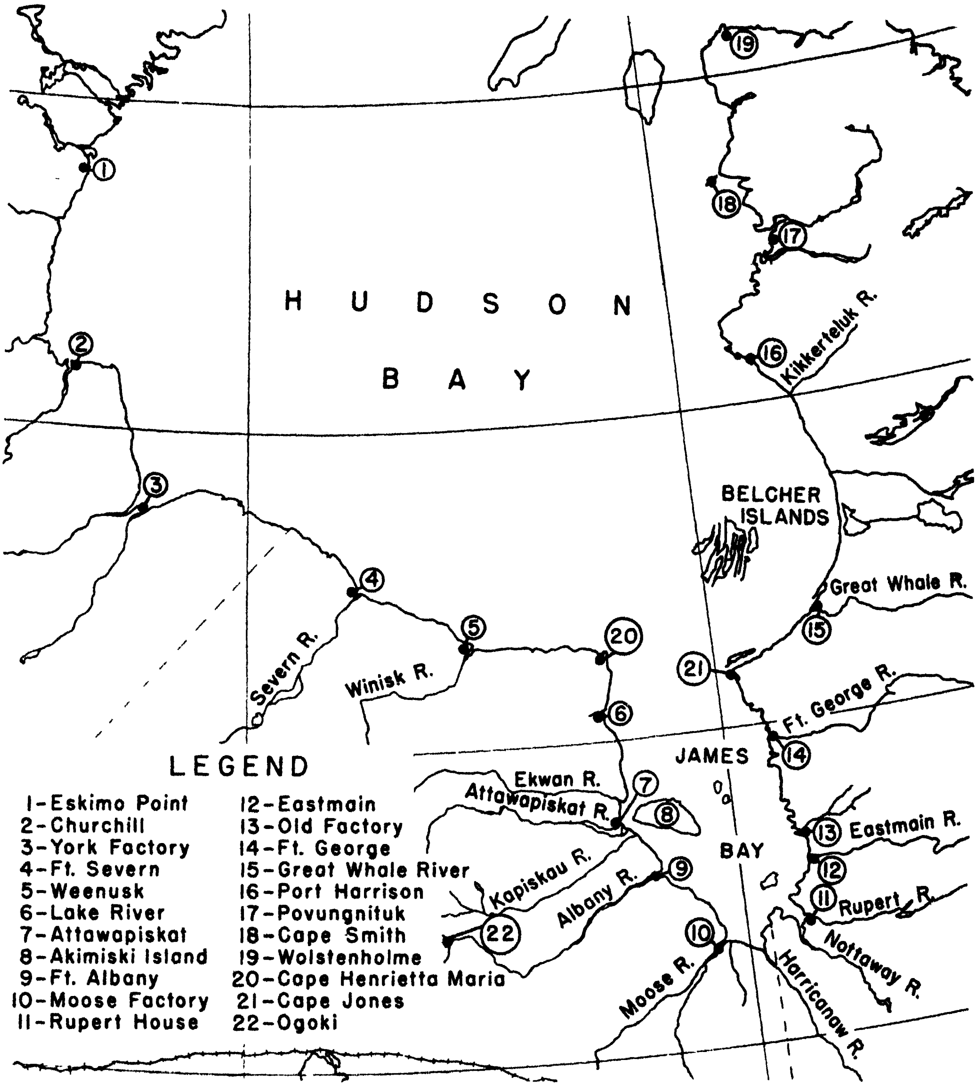

Fig. 2.—Map of the Hudson-James Bay range of Canada geese that winter in the Mississippi River valley. The main breeding range of this goose population is between the Severn and the Albany rivers.

have visited the Jack Miner Bird Sanctuary at Kingsville, Ontario, to study trapping operations. The first traps built at Horseshoe Lake, although set on land, were modeled after the water trap perfected by the Miners. In May, 1945, the authors visited Kingsville to obtain background material requisite for compiling and interpreting Miner band-recovery data. The Miner records consisted of the original reports of band recoveries from hunters in the United States and Canada, and from missionaries and fur traders in the far north, who reported recoveries made by the natives. The senior author was responsible for the compilation of these original data, which are filed in Ottawa at the Dominion Wildlife Service, Canada Department of Mines and Resources.

Between 1915 and the spring of 1944, approximately 31,000 Canada geese were banded at the Miner Sanctuary. From these bandings approximately 3,900 rec-

Table 2.—Number of Canada geese banded at the Jack Miner Bird Sanctuary, Kingsville, Ontario, during the fall trapping seasons, 1927–1944.

Year	Geese Banded	Year	Geese Banded
1927	50	1936	660
1928	558	1937	1,741
1929	225	1938	604
1930	578	1939	1,606
1931	1,091	1940	1,182
1932	1,129	1941	1,235
1933	1,490	1942	1,167
1934	468	1943	1,294
1935	170	1944	984
Total			*16,232*

ords of recoveries had been received by 1944. Although exact records are not available for the early years, it is estimated that about one-half of the 31,000 geese were banded in the autumn months, table 2, when many geese of the Mississippi flyway migrate through the Kingsville region. A comparatively small number of the geese of this flyway migrate through Kingsville in spring. Recovery records from fall-banded geese for which sufficient data are available have been analyzed for use in this paper.

Because of their sheer mass and the span of years they cover, data from the Miner bandings are outstanding in the annals of wildlife study. That the bandings have not yielded findings commensurate with their size is understandable, as they were begun at a time when little was known about sexing and aging of Canada geese.

Because Jack Miner did not serially number his bands, some of the potential values of his bandings will never be realized. Prior to 1932, his bands were marked with symbols to represent only the season and year in which they were used. For example, "25 S" meant 1925 spring; "25 F" meant 1925 fall. Since 1932, all bands have been stamped with an additional letter to signify the date of banding, and, since the fall or autumn of 1946, all bands have also been serially numbered.

Fig. 3.—Noon stop on the Albany River, June 1947. Canoe and plane are the only means of travel in much of the breeding range of the Mississippi Valley geese.

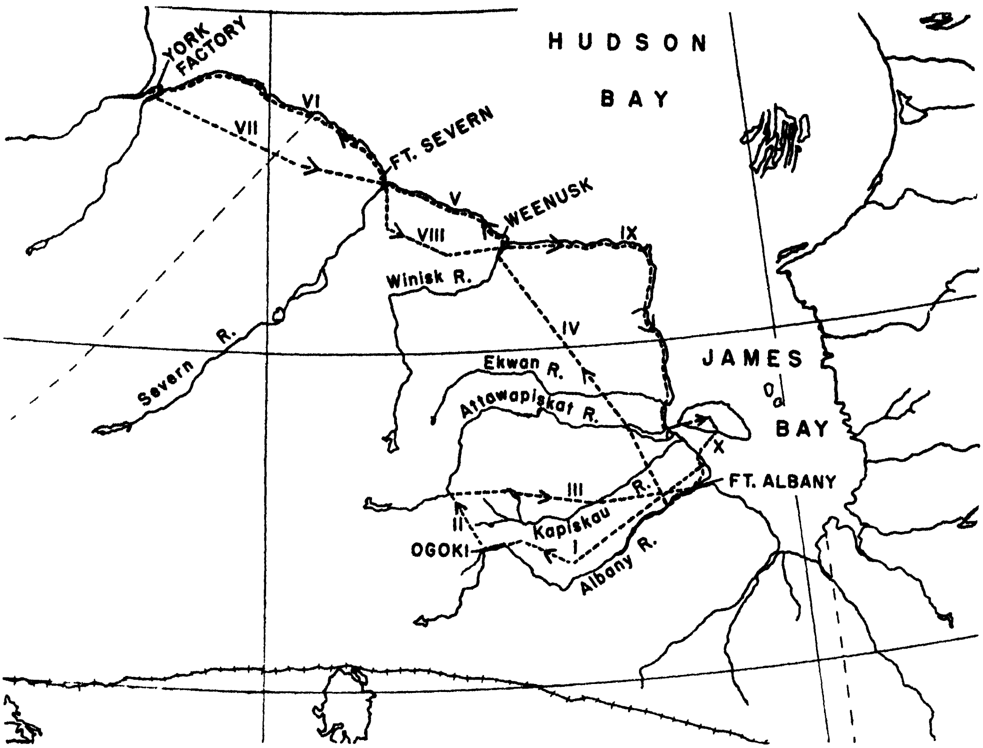

Fig. 4.—Map showing flight routes of an aerial reconnaissance of the breeding grounds of Canada geese south of Hudson Bay and west of James Bay in 1947. Roman numerals designate the various flights discussed in the text.

Recovery records for the first 8 years are incomplete, as many of the letters reporting bands were given to newspapers and never returned. In some cases only news clippings with incomplete data served to preserve early records.

Data From Other Areas

Field studies on Canada goose concentrations away from Horseshoe Lake were begun by the junior author in 1942. Beginning in 1943, he inventoried by plane many of the wintering concentrations from Horseshoe Lake to Louisiana. He devoted the summer of 1943 to a survey of the south and east coast areas of James Bay, from Moose Factory, Ontario, to Fort George, Quebec, fig. 2. The following summer he made a reconnaissance of the west coast from Moose Factory to Cape Henrietta Maria.

The senior author made a brief preliminary trip to James Bay in the summer of 1946, visiting Moose Factory, Rupert House, and Fort Albany, and ascending Little Partridge Creek via canoe. In 1947, he spent from mid-May to September investigating the breeding grounds inland from the west coast of James Bay; he used both canoe, fig. 3, and plane for these surveys. The aerial reconnaissance in 1947 included stops at Weenusk, Fort Severn, and York Factory. Approximately 375 aerial photographs were taken on this aerial survey, the itinerary of which is shown in fig. 4.

Data From Questionnaires

Approximate'y 40 questionnaires regarding goose-breeding grounds and kills were distributed to fur trade posts in the Canadian Eastern Arctic in 1947, through the courtesy of the administration of the Northwest Territories, Canada Department of Mines and Resources. Replies to the questionnaires have been summarized and the data included in this report.

THE FLYWAY CONCEPT

Over a decade ago, Lincoln (1935) presented the concept that the routes taken by North American birds in migration fall into major flyways or lanes of travel. Recoveries of banded birds have demonstrated the validity of the flyway concept with respect to waterfowl as well as many other kinds of birds. Lincoln named the Atlantic, the Mississippi, the Central, and the Pacific flyways as the principal ones of North America.

The limits of the waterfowl flyways vary somewhat with each species and may change to some degree from year to year, depending on weather, surface water, and food conditions. In most species the populations of one flyway merge almost imperceptibly with those of adjoining flyways. Consequently, the flyway taken in any one year by an individual bird breeding in an area where two flyways meet may be due in part to chance.

The adherence of ducks and geese to their ancestral flyways has been demonstrated experimentally by removing individuals from one flyway to another. With relatively few exceptions, the transported individuals have been recorded later in their original flyways. One of the early experiments of this kind with ducks was begun in 1918 by McIlhenny (1940), who, in co-operation with Dr. Arthur A. Allen of Cornell University and the United States Bureau of Biological Survey, shipped ducks and coots trapped during the winter in Louisiana, which is in the Mississippi flyway, to points in the Atlantic and Pacific flyways. Most of the released individuals that were later recovered or retrapped were taken in the Mississippi flyway.

Perhaps the earliest test of this kind with Canada geese was made by Jack Miner; complete data on the test were found in the files of the Dominion Wildlife Service. In the spring of 1934, 25 geese trapped at the Miner Sanctuary, from flocks that had wintered on the Atlantic Coast and were in migration to their breeding grounds along the east coast of James and Hudson bays, were released among a concentration of blue and snow geese at Grant Lake, Manitoba, a locality far west of their own migration routes. Three of these geese were later reported shot, two of them in their own flyway: one in the vicinity of Poplar Branch, North Carolina, in the fall of 1934; the other near Lake St. John, Quebec, in the fall of 1940. The third was recovered in northern Manitoba in the spring of 1934, too soon after release for the record to be significant.

The chief deviations from flyway consciousness are among young birds that have not yet nested (Lincoln 1934). Williams & Kalmbach (1943) showed that the migratory behavior of young Canada geese when raised in or transported to a new area is similar to the behavior of geese native to that area.

As pointed out by Lincoln (1935), the adherence of waterfowl to their ancestral flyways has particular administrative significance in connection with conserving the continental waterfowl resources. "It indicates," Lincoln writes, "that if the birds should be exterminated in any one of the four major flyways now definitely recognized, it would at best be a long time before that region could be repopulated, even though birds of the species affected should continue over other flyways to return to their great breeding grounds of the North."

This hypothesis is of special significance as applied to the management of Canada geese. Members of a species with a fairly low breeding potential, they would probably require several years to regain their numbers in any one flyway after having been once seriously depleted. Thus, it is to the hunter's best interests that the yearly kills in each flyway be kept within reasonable bounds.

EASTERN POPULATIONS

A brief review of the distribution and taxonomy of Canada goose populations in eastern North America is relevant to an understanding of the data later presented concerning the Mississippi flyway population.

The Canada geese using the Atlantic and Mississippi flyways, as defined by Lincoln (1935), have been recognized as belonging to two distinct major populations, based on taxonomy (Todd 1938)

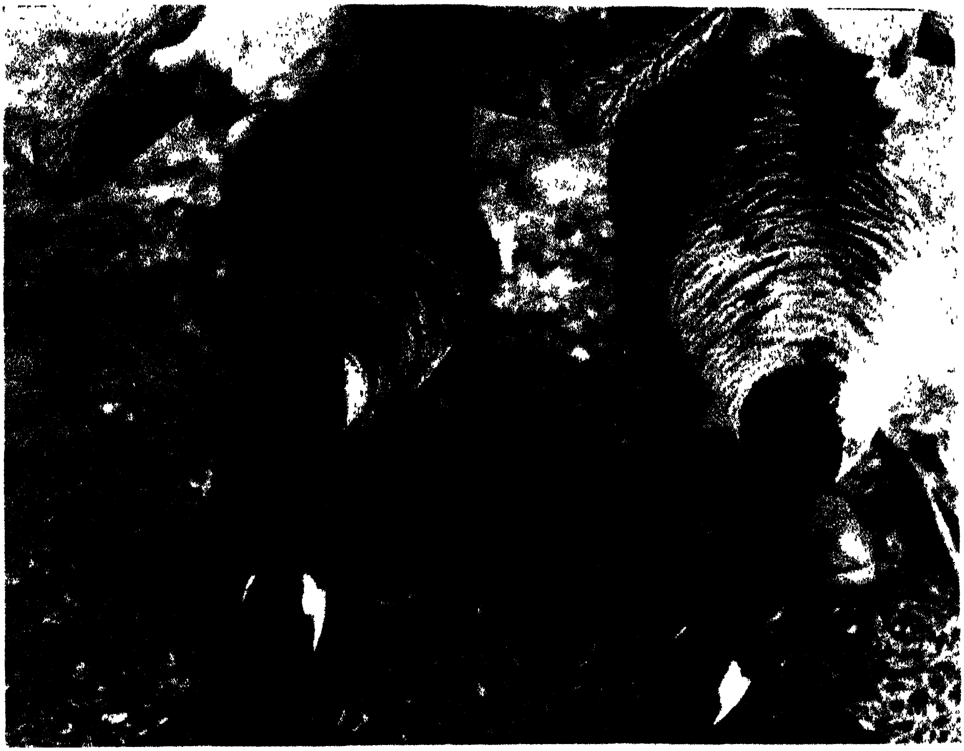

Fig. 5.—Extreme examples of plumage variation in Canada geese of the flock wintering at Horseshoe Lake in southern Illinois. The majority of the geese at Horseshoe Lake approach the dark-colored goose, left above, considered to be *Branta canadensis interior;* but a few resemble the individual at the right. The latter is more like *Branta canadensis canadensis* of the North Atlantic coast. The goose on the left is a yearling female; that on the right, a yearling male.

and location of the breeding grounds: the North Atlantic population and the Hudson-James bay population. The North Atlantic population constitutes a distinct management unit. The study reported here indicates that the Hudson-James bay population is not homogeneous but consists of four subpopulations, each of which constitutes a separate management unit having a fairly distinct range of its own. These subpopulations are here designated by terms suggestive of their wintering grounds or migration routes: the South Atlantic, the Southeast, the Mississippi Valley, and the Eastern Prairie.* The ranges of these subpopulations are shown in fig. 6.

Todd (1938) noted what he considered significant plumage differences among Canada geese collected in the eastern half of the United States and proposed a new subspecies, *Branta canadensis interior,* for the darker colored birds that breed and migrate in an area west of the range of the nominate subspecies, *Branta canadensis canadensis.* Fig. 5 shows two Canada geese trapped at Horseshoe Lake with plumages that illustrate some of the differences between these two races.

"Typical *canadensis,* as represented by breeding examples from Newfoundland and by winter birds from the South Atlantic coast, is a comparatively light-colored bird," according to Todd (1938). "In breeding dress the anterior under parts are buffy white, and this pale color runs up on the sides of the lower neck (behind the black) to form a conspicuous light-colored area on the upper back. In the new race this feature is wanting. The feather-edgings of the new

* Name and recognition of the Eastern Prairie population as a separate population from Cecil S. Williams of the United States Fish and Wildlife Service, 1946.

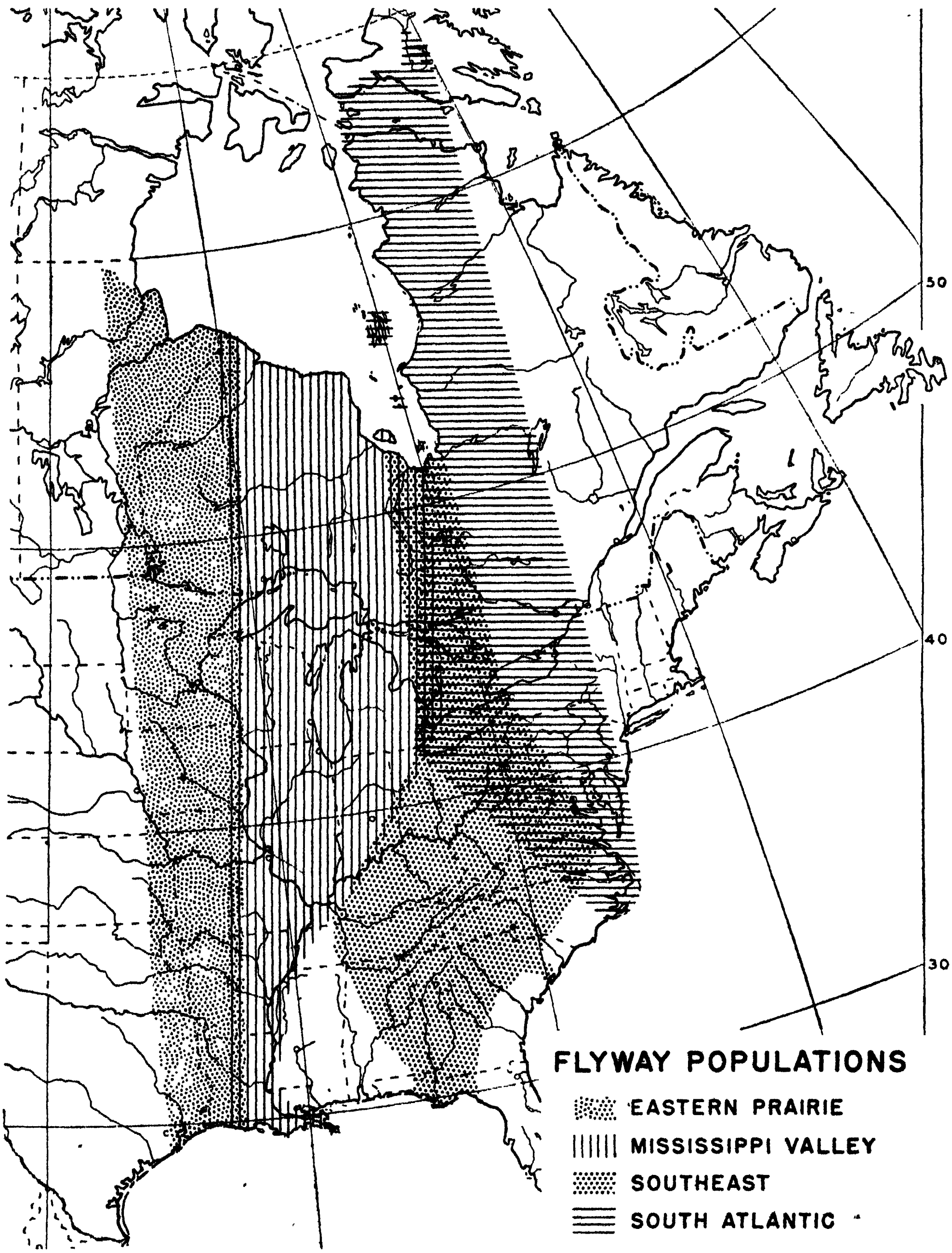

Fig. 6.—Map showing roughly the main ranges of the four populations of Canada geese nesting in the Hudson-James bay region. The range of the Mississippi Valley geese overlaps the range of the Southeast population chiefly in fall; the range of the South Atlantic population overlaps the range of the Southeast population chiefly in spring. The western limits of the range of the Eastern Prairie population extend farther west than indicated here. The eastern limits of the range of the South Atlantic population probably extend farther east in some areas than indicated.

race are generally darker, while the under-plumage is conspicuously so."

Official recognition was given to the race *interior* by its inclusion in the *Twentieth Supplement to the American Ornithologists' Union Check-List of North American Birds* (Wetmore 1945). Appendix B contains a brief summary of the latest classification of the Canada geese of the genus *Branta,* with notes regarding recognition of various kinds by the Indians.

North Atlantic Population

The Canada geese of the North Atlantic, which breed in Newfoundland, eastern Quebec, and Labrador north to the northern limit of trees (Austin 1932), are those recognized by Todd (1938) as *Branta canadensis canadensis.* In the autumn, they migrate down the Atlantic Coast and winter principally from Port Joli and Port l'Hebert, Nova Scotia (Tufts 1932, Lloyd 1923), to Martha's Vineyard, Massachusetts, and south probably as far as New Jersey. Skins examined by us at the Chicago Natural History Museum indicate that some of these geese winter as far south as the coast of North Carolina, where they mingle with South Atlantic geese.

Low (1935), in a report on 64 Canada geese banded at Cape Cod, Massachusetts, presented convincing evidence that the flight of geese along the North Atlantic Coast is a distinct entity. Twenty-five of the 26 geese later recovered or recaptured were taken between Newfoundland and New Jersey. One was recovered in Florida.

Hudson-James Bay Populations

The Canada geese that breed inland from both coasts of Hudson and James bays, fig. 2, as far north on the west coast as Churchill, Manitoba, and probably as far north on the east coast as Baffin Island, which lies just north of Cape Wolstenholme, conform to the description given by Todd (1938) for *Branta canadensis interior.* While the distribution of geese breeding around the two bays is more or less continuous, available data indicate that this population is a heterogeneous one and is composed of the four segments or subpopulations previously named: the South Atlantic, the Southeast, the Mississippi Valley, and the Eastern Prairie. Each has its own breeding range, migration routes, and wintering areas, figs. 6 and 7. The existence of two of the population divisions that nest in the Hudson Bay area, one wintering along the central Atlantic Coast and the other in the Mississippi River valley, was first pointed out by Manly Miner (1931). This discovery, based on band recoveries, was due in part to the fortuitous location of the Miner Sanctuary, fig. 12, which lies about midway between the migration routes of these populations and thus permits banding of both populations.

South Atlantic Population.—This population is distributed in winter along the Atlantic Coast from southern New Jersey to Chesapeake Bay, Back Bay (Virginia), Pamlico Sound, and Currituck Sound, and Hyde and Dare counties, North Carolina. Recoveries from geese migrating through the Miner Sanctuary in the spring, and banded there in that season, reveal that Lake Mattamuskeet in Hyde County, North Carolina, has in recent years become the most important wintering area of this population.

A portion of the birds in this population stop at the Miner Sanctuary while en route to their breeding grounds, which are on the Belcher and probably the Twin Islands and in suitable localities along the east coast of James and Hudson bays, and inland probably to the height of land, as suggested by Todd (1938). Band recoveries indicate that the breeding range may include a portion of southern Baffin Island, fig. 7. Large numbers of recoveries reported from a post or small area may actually have been taken along extensive areas of the coast. For instance, recoveries plotted as from the Belcher Islands in fig. 7 also include the recoveries from the east coast of Hudson Bay from Cape Jones to Nastapoka Falls; recoveries represented as from the Port Harrison area actually include the recoveries made along the east coast of Hudson Bay from the Kikkerteluk River area to the Povungnituk area.

Southeast Population.—The existence and range of the Southeast population was revealed when band recoveries

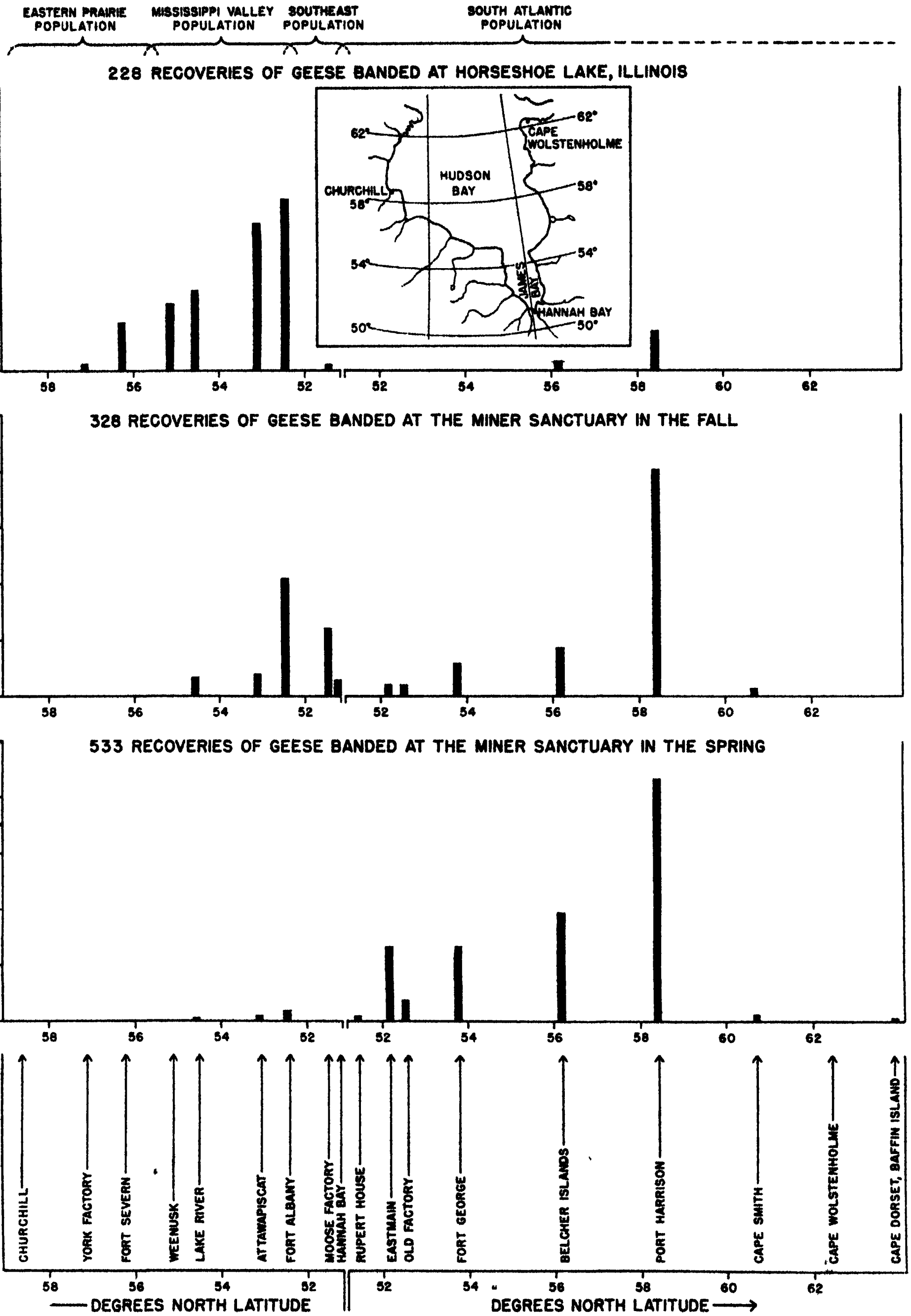

Fig. 7.—Band recoveries in the Hudson-James bay region from Canada geese banded at the Horseshoe Lake Game Refuge and at the Jack Miner Bird Sanctuary. Shown here are the percentages of the total recoveries from the Hudson-James bay region for various outposts and fur-trade posts. In some cases, large numbers of recoveries reported from a post or small area have actually been taken along extensive areas of the coast line. For instance, recoveries plotted as from the Belcher Islands also include recoveries from the east coast of Hudson Bay.

from the Miner autumn-banded geese were plotted as to exact locality. These recoveries show that the autumn flight of geese through the Kingsville, Ontario, area is not homogeneous, but is composed of two populations of geese: the Southeast population and the Mississippi Valley population, figs. 6 and 7. The Southeast population breeds inland from the south coast of James Bay and winters in the inland regions of the southeastern states. A detailed discussion of the range of the Southeast population is presented in Appendix A.

Mississippi Valley Population.—The range of the Canada goose population that winters in the valley of the Mississippi River extends in autumn and winter from western Michigan west through the eastern portions of those states lying immediately west of the Mississippi River and south in the valley of this river to the coast of the Gulf of Mexico. The main winter range south of Cairo, Illinois, does not extend greatly beyond the immediate valley of the Mississippi River except in Arkansas and Louisiana. The Mississippi Valley population, which is given primary consideration in this paper, breeds inland from the west coast of James Bay and the south coast of Hudson Bay, figs. 6 and 7.

Eastern Prairie Population.—The eastern range limits of the Eastern Prairie population seemingly merge with the western range limits of the Mississippi Valley population on the breeding grounds in the muskeg between Fort Severn and Fort York and on the wintering grounds in western Louisiana, figs. 6 and 7. The eastern range limits of the Eastern Prairie geese in migration are apparently in central parts of Minnesota, Iowa, Missouri, Arkansas, and Louisiana. We do not have the data at hand to discuss the western limits of the range of this population, nor are they of concern in this paper.

HUDSON-JAMES BAY BREEDING RANGE

The Canada goose has long been a staple food item for the natives of North America. To the white man in the United States and Canada, it has been a highly prized hunting trophy as well as an esteemed table bird. Formerly the species nested over much of the upper Mississippi River valley (McClanahan 1940), but, subjected to intensive hunting pressure, it was soon extirpated as a breeding bird from most of this country. Probably the only reason that there are still Canada geese to winter in the Mississippi River valley is that much of the country adjacent to Hudson and James bays in northern Ontario, where most of this migratory population breeds, is relatively inaccessible to man in summer.

Limits of Range

The general limits of the range of the Canada goose in the Hudson-James bay area have not been adequately summarized in previous publications. The existence of only two of the four populations that nest adjacent to these bays has been recognized previously, and the limits of their ranges have not been well defined. For these reasons, in addition to presenting new data on the Canada goose breeding range in the region of Hudson and James bays, we review pertinent references in the literature.

Until the race *Branta canadensis interior* was recognized by the American Ornithologists' Union (Wetmore 1945), most of the writers who mentioned the Canada goose either made no distinction between the two races of *Branta canadensis,* or they referred to birds of both races as belonging to the race *canadensis.* References in the literature prior to 1945 to either of these races should be interpreted in the light of the recent decision by the A.O.U.

The sequence of the following citations is in general according to the geographic position of the localities concerned: from north to south on the west side of the bays and from south to north on the east side.

The northern limit of the breeding range of *Branta canadensis interior* west of Hudson Bay coincides roughly with the northern limit of trees as delineated by the distribution of black spruce and white spruce, fig. 8. Taverner & Sutton (1934) found that at Churchill, Manitoba, which is "precisely at the limit of tree growth, where the spruce forest dies out on the

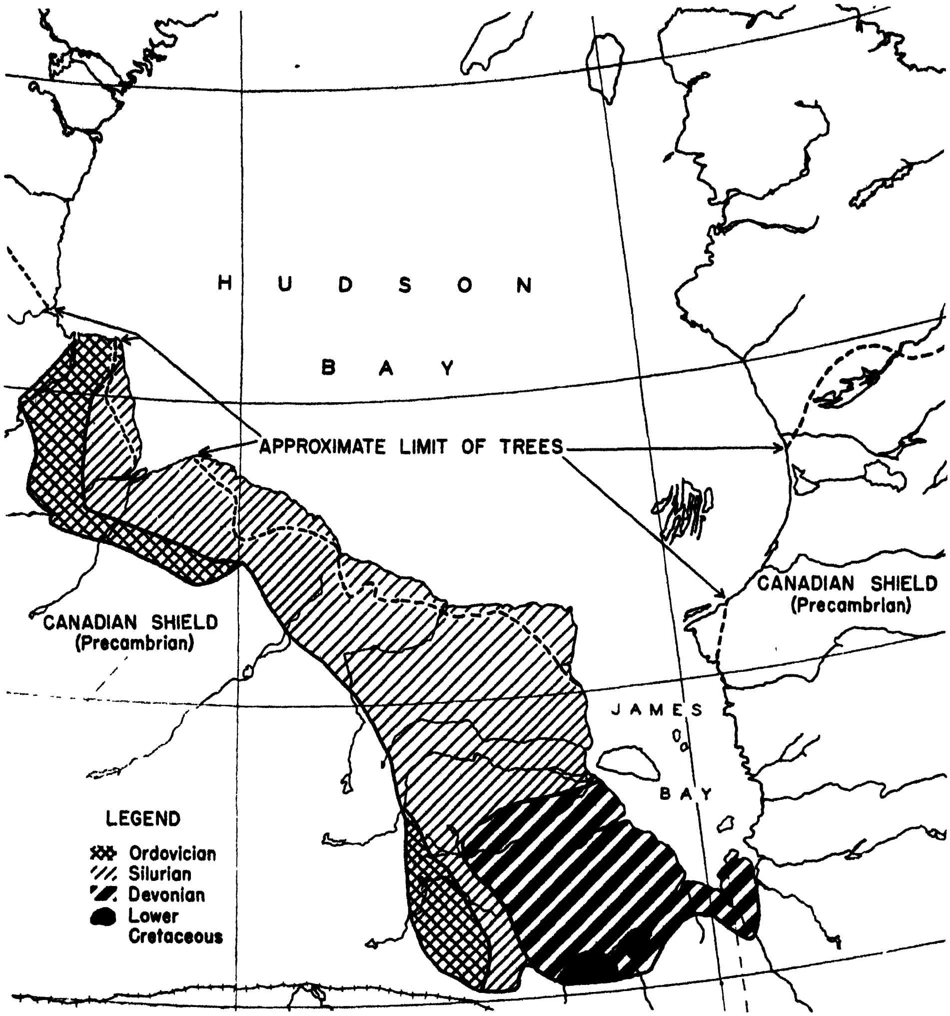

Fig. 8.—Map showing subsurface geological structures south and west of Hudson and James bays. Approximate limit of trees from official Canadian map. The principal nesting range of the Mississippi Valley Canada goose population lies within the shaded area.

arctic tundra and both types of biological association are in contact," the goose they referred to as *Branta canadensis canadensis* "is a common transient, which breeds sparingly in the vicinity."

Preble (1902) recorded that when he was in the region west of James Bay and Hudson Bay considerable numbers of *Branta canadensis* were reported as nesting on an island in Lake Winnipeg. He saw or had reliable reports of young geese along the Fox, the Churchill, and other rivers of the region.

Bell (1880) stated that *Anser canadensis* "breeds in considerable numbers along the Churchill River."

Grinnell & Palmer (1941) reported that "birds [*Branta canadensis*] were seen and heard at intervals from June 6 on" in the vicinity of Churchill.

Allen (1945) recorded nests and nesting pairs of *Branta canadensis* near Churchill.

Traverner (1931) wrote: ". . . . it [*Branta canadensis candensis*] is the common breeding goose of James and Hudson bays for most of the east coast and the west side at least as far as

Churchill, probably stopping somewhere south of cape Eskimo where it appears to be replaced by *leucopareia*." From the barren grounds north of Churchill, the lesser Canada goose, *Branta leucopareia leucopareia* is the common representative of the genus *Branta*.*

Hørring (1937) examined parts of 10 individuals, mainly from Baker Lake, a locality 385 miles nearly due north of Churchill, which he assigned to the race *leucopareia*.

A female goose taken May 20, 1937, at Eskimo Point, on the coast of Hudson Bay north of Churchill, appeared to Shortt & Peters (1942) "to be of the form *leucopareia*."

Specimens taken along the Thelon River, which is in the districts of Mackenzie and Keewatin, Northwest Territories, were "referred by P. A. Taverner to *B. c. leucopareia*" (Clarke 1940).

There are numerous references in the literature regarding the occurrence of the Canada goose south of Hudson Bay and west of James Bay. Richardson (1851) quoted a report of George Barnston, an officer of the Hudson's Bay Company at "Martin's Falls," a post on the Albany River 200 miles inland from James Bay, in which mention is made of "geese and ducks hatching" in the vicinity.

Bell (1887), describing his exploration of the Attawapiskat River, wrote: "The Canada goose breeds in considerable numbers in the open swamps behind the wooded borders of the lower section of the river, and the young birds, ready to fly, were congregating in flocks, all along the lower stretch, in the end of August and the beginning of September."

Baillie & Harrington (1937) wrote: "The Canada Goose breeds fairly commonly along the coasts of James and Hudson bays, between Moose river and Churchill."

South of James Bay the principal breeding range of the Canada goose may not extend more than 60 miles inland from the coast. In 1926, a mining party led by B. C. Lamble explored the country between Timmins, Ontario, and James Bay. During the trip they "saw many broods of Canada geese, but none farther south than Kesagami Lake, Latitude 50° 30′" (letter to Jack Miner from B. C. Lamble, August 5, 1926).

In regard to the status in other parts of Ontario of the bird they regarded as *Branta canadensis canadensis*, Baillie & Harrington (1937) stated: "Recent maps indicate, perhaps correctly, that this bird may breed in the whole of northern Ontario, north of Lake Superior and the southern end of James Bay.

"The several instances of this bird nesting in southern and central Ontario almost undoubtedly concern injured or semi-domesticated individuals."

Bell (1883), who was undoubtedly intimately familiar with most of the province of Ontario, stated that "between the great lakes and James' Bay, only chance pairs lag behind in their northward flight to hatch their broods."

Inland from many parts of the east coast of Hudson and James bays, and on the islands along the coast and to the north, suitable habitat for nesting Canada geese is less extensive than inland from the west coast. Consequently, nesting on the east side of the bays is relatively concentrated although, in the interior of northern Quebec (Ungava), more widely scattered nesting is found.

The late James Watt, former manager of the Hudson's Bay Company post at Rupert House, wrote the junior author (letter of December 25, 1943) that "While travelling in the interior [south and east of James Bay] surveying beaver lands and counting lodges I have seen as many as 15 to 20 nesting [Canada] geese in a day's travel—all with broods of young geese, and . . . . taking into consideration the immense territory and number of lakes and inland waterways, the number of geese that nest inland must be large."

A. P. Low (1896) wrote: The Canada goose "breeds in marshes throughout the northern interior [of Quebec], and is seen along the rivers with young broods about July 1st; . . . . . several large broods seen on Burnt Lakes, Romaine River; not common at Lake Mistassini, but abundant on East Main River—especially on lower part, where the river is cut out of clays, with good bottomlands; breeds in large numbers on the islands of James Bay."

* See Appendix B for discussion of recent revision by Hellmayr & Conover (1948).

In reply to the questionnaire sent out in 1947, Roy Jefferies, Post Manager at Eastmain for the Hudson's Bay Company, in collaboration with an Indian, stated that Canada geese nested in a swamp about 10 miles south of Eastmain.

It is common knowledge in the James Bay area that considerable concentrations of nesting geese are found on the Twin Islands in James Bay, particularly the South Twin, and on the Belcher Islands in Hudson Bay, fig. 2. Nesting pairs are also found on Charlton Island and a number of smaller islands along the east coast of James Bay.

In the summer of 1947, Donald F. Coates and Donald B. Coombs (personal communication), observers for the Geodetic Service of Canada, visited the following islands in James Bay: North Bear, Bear, South Bear, Bare, Grey Goose, Walter, North Twin, Weston, and Charlton. They found Canada geese on only three of these islands. On Grey Goose, their guide shot two geese but they found little evidence of breeding pairs; on Weston, they saw about 20 pairs, in one instance 6 adults and 21 goslings together on one pond; and on Salt Lake, at the northern tip of Charlton, they observed 1 pair and 6 goslings.

Bell (1883) found that Canada geese "breed on the islands along the east coast of Hudson's Bay . . . . . it is said that very few Canada geese breed northward of Hudson's Strait."

Manning (1946) mentioned "a considerable number of geese in the Mistake Bay area at the end of July." (Mistake Bay is between Povungnituk and Port Harrison, fig. 2.) He "saw 10 or 15 of them, and all belonged to the large form." He identified them as *Branta canadensis interior*.

In a recent letter (to the senior author, April 11, 1947), T. H. Manning states that he believes the chief breeding ground of Canada geese in this area is between Cape Dufferin (near Port Harrison) and the Cape Smith Range. "I do not . . . think that they often nest on the coastal islands. They may nest on, the King George and Sleeper Islands, but the Ottawa Islands are high, rocky and barren, and unsuitable. I have no direct evidence, but I should think they nest throughout the interior between Hudson and Ungava bays."

The Reverend H. S. Shepherd, missionary at Port Harrison, Quebec, for 2 years, stated in the questionnaire sent out in 1947 that scattered nesting of Canada geese is found over a large area of the interior inland from Port Harrison, but that the total number is not great.

Low (1902) found that, in the country about 12 miles south of the Digges Islands,* "The many small ponds and swamps that occur between the boulder ridges are favorite breeding places for grey geese." Farther south, about 30 miles north of the Povungnituk River, Low also found large numbers of Canada geese about 10 miles inland from the mouth of the Sorehead River.

In the Povungnituk area, W. A. Tolboom, a post manager, reported by questionnaire in 1947 that nesting is well scattered over a wide area and that generally speaking all nests are found on islands, on lakes or shores of lakes, seldom on rivers, and very seldom on coastal islands.

Manning's surmise regarding goose nesting over the Ungava Peninsula is substantiated by Rousseau's (1948) finding that the Canada goose is one of the few prevalent forms of wildlife between Povungnituk and Payne Bay post on Ungava Bay.

A few individuals of the Canada goose nest on the arctic islands north of the Canadian mainland. Sutton (1932) reported that Eskimos have occasionally found nests of *Branta canadensis canadensis* on Southampton Island.

Shortt & Peters (1942) reported an immature "specimen referable to *B. canadensis canadensis*" taken August 17, 1938, at Lake Harbour, southern Baffin Island.

Soper (1946) reported that *Branta canadensis canadensis* breeds on Baffin Island along the southern coast of Foxe Peninsula, and from at least Amadjuak Bay to Gabriel Strait along the coast of Hudson Strait.

Mississippi Valley Population.—The limits of the breeding range of each

* Small islands lying off the extreme tip of Ungava, northern Quebec.

of the four populations of *Branta canadensis interior* around Hudson and James bays have been deduced from band recoveries, coupled with a knowledge of the suitable nesting country, figs. 6 and 7. In ascertaining the true distribution of each of these populations, we were fortunate that the Miner banding records, as well as the Horseshoe Lake records, could be analyzed. An interpretation of either the Horseshoe Lake records or the Miner records alone would undoubtedly have led to erroneous conclusions, whereas the two sets of data considered together supplemented each other.

Band-recovery data from the Hudson-James bay area are in large measure dependent upon the native Indians. When interviewed through interpreters, the Indians are usually able to furnish the exact date and place of each band recovery. However, if only the name of the post is known at which a band is secured, the location of the recovery can be approximated, as usually the native groups from the various fur trade posts, including even individual families, use the same hunting grounds year after year. The approximate boundaries of the hunting grounds of the various bands of Indians on the west and south coasts of James Bay is shown in fig. 9, which is copied from a portion of a map prepared by the Reverend John M. Cooper to ac-

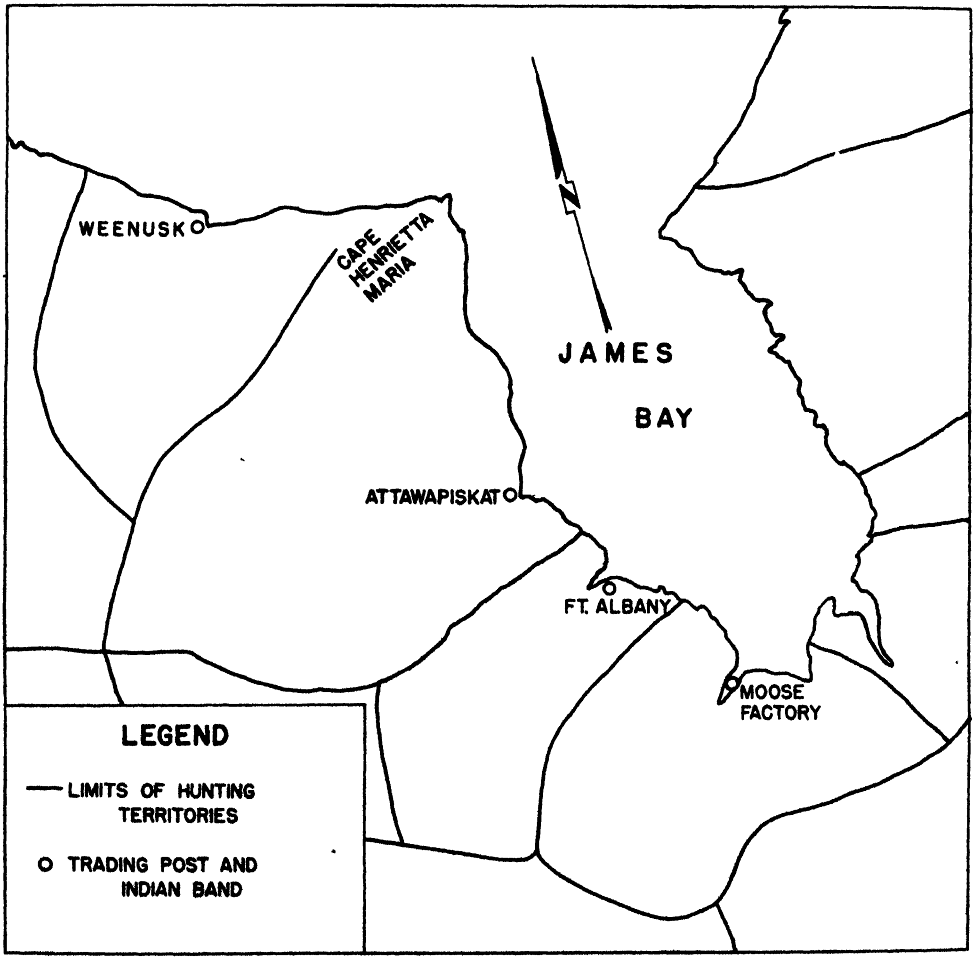

Fig. 9.—Map showing limits of the trapping and hunting grounds of the various bands of Cree Indians west and south of Hudson and James bays. (After Cooper 1933.)

Table 3.—Canadian breeding grounds of the Mississippi Valley Canada goose population, as indicated by spring and summer band recoveries from the Horseshoe Lake flock, 1941–1947.

River or Island	Unknown Except by Post or River	Number of Recoveries and Approximate Point of Recovery — Number of Miles Inland by River From Coast of Hudson or James Bay*												Total
		0–9	10–19	20–29	30–39	40–49	50–59	60–69	70–79	80–89	90–99	100–109	150	
Severn River	13	3					1			1				18
Winisk River	5	4	1				1		2				12	25
Sutton River		2												2
Kinusheo River	2													2
Lake River	32													32
Nowashe Creek	3			1										4
Swan River	5													5
Neatalkau River							3							3
Ekwan River						5	1		1			1		8
Attawapiskat River	16	2	3		2	3	1	1			3			31
Akimiski Island	4													4
Kapiskau River							3		1					4
Albany River	1	12		1	6	8	14	6	1	1				50
Stooping River	1								1					2
Kinoje River	5													5
Nettichi River	2	2												4
Lawapiskau River	1													1
Total	*90*	*25*	*4*	*2*	*8*	*16*	*24*	*7*	*6*	*2*	*3*	*1*	*12*	*200*

*Nearly all distances given by the Indians were in multiples of 10. Most of the band recoveries were from the 30–59-mile zone inland from the coast.

company his unpublished report to the Indian Affairs Branch in Ottawa. Father Cooper's map is based on his field studies of 1927, 1932, and 1933 in the vicinity of James Bay.

According to Father Cooper, the boundary lines of hunting territories generally are represented by natural landmarks, such as heights of land, chains of lakes, or watersheds. Hunting rights to each foot of land are owned by some Indian and are acquired only through inheritance or donation. Territory is generally inherited in the male line and most family territories have been in the same family line for generations. As to the accuracy of these boundaries, Father Cooper writes: "These limits are and can be only approximate as we have not adequate and detailed maps based on surveys of the whole area. . . . . The Moose Indian grounds and to a certain extent the Rupert House grounds are plotted as of a generation ago. Some changes through inheritance and through the dying out of certain families, particularly around Lake Kesagami, have occurred, but in the main the present Indian families still hunt each where the father and grandfathers hunted."

Band recoveries from the Canadian breeding grounds of geese banded at Horseshoe Lake are summarized in table 3. These recoveries, important in revealing the location and extent of the breeding range of most of the Mississippi Valley geese, do not, however, take into account geese that nest in the United States, where several efforts to establish breeding flocks on federal, state, and private refuges are making increasingly important contributions to the Mississippi Valley population.

Most of the Horseshoe Lake bands recovered in Canada were taken in the muskeg country lying inland from the coasts of James and Hudson bays between the Kinoje* and Severn River watersheds, fig. 30. Band recoveries indicate that during the breeding season this enormous section of muskeg country, roughly triangular in outline, contains the bulk of the geese that winter in southern Ontario, Michigan, Wisconsin, Indiana, Illinois, eastern portions of Minnesota, Iowa, Missouri, Arkansas, Louisiana (Delta), western Kentucky, western Tennessee, and western Mississippi. The barren grounds of Cape Henrietta Maria and the coastal marshes probably do not contain breeding birds, but nesting occurs on Akimiski Island, figs. 2 and 30, which lies in James Bay a few miles east of the mouth of the Attawapiskat River.

Of the tremendous area of muskeg outlined above, only a relatively small portion is either suitable for, or attractive to, nesting geese. Field observations, as well as band recoveries, indicate that the main breeding range of *Branta canadensis interior* south of Hudson Bay and west of James Bay is within an enormous area of muskeg, the limits of which coincide roughly with the area underlaid with sedimentary rocks of the Paleozoic era, fig. 8. These rocks, of the Ordovician, Silurian, and Devonian periods, are covered by a mantle of glacial drift over which the flat muskeg is superimposed. According to Bell (1887), "The drift (principally boulder-clay) which overspreads the palaeozoic basin westward of James' Bay appears to be a continuous sheet varying probably between thirty and ninety feet as far as can be judged by the sections along the rivers."

Ells (1912) believes that fairly uniform timber and land conditions prevail concentrically from James Bay except for minor variations, depending on primary and secondary drainage.

> Thus, if we have a 5 ft. muskeg at a distance of thirty miles south of James Bay, I would look for a similar condition East and West along a belt roughly parallel with the shores of the Bay. . . . . This assumption I have based on the fundamental principle that the country adjacent to James Bay on the South and West side is gradually being elevated . . . . . As we leave the shores of James Bay, the depth of the muskeg should gradually increase . . . . Eight miles to the west of Moose Factory the depth of moss and muck is 2 ft. to 3 ft.; 10 miles further south the depth is 2 ft. to 4 ft.; and 40 miles, 4½ to 5 ft.; at 60-80 miles, 5½ to 6 ft.; and at 90 miles the depth is 6 to 8 feet.

Evidence that the main breeding grounds of the Mississippi Valley Canada

* A small river that flows into James Bay 8 miles south of the Albany River.

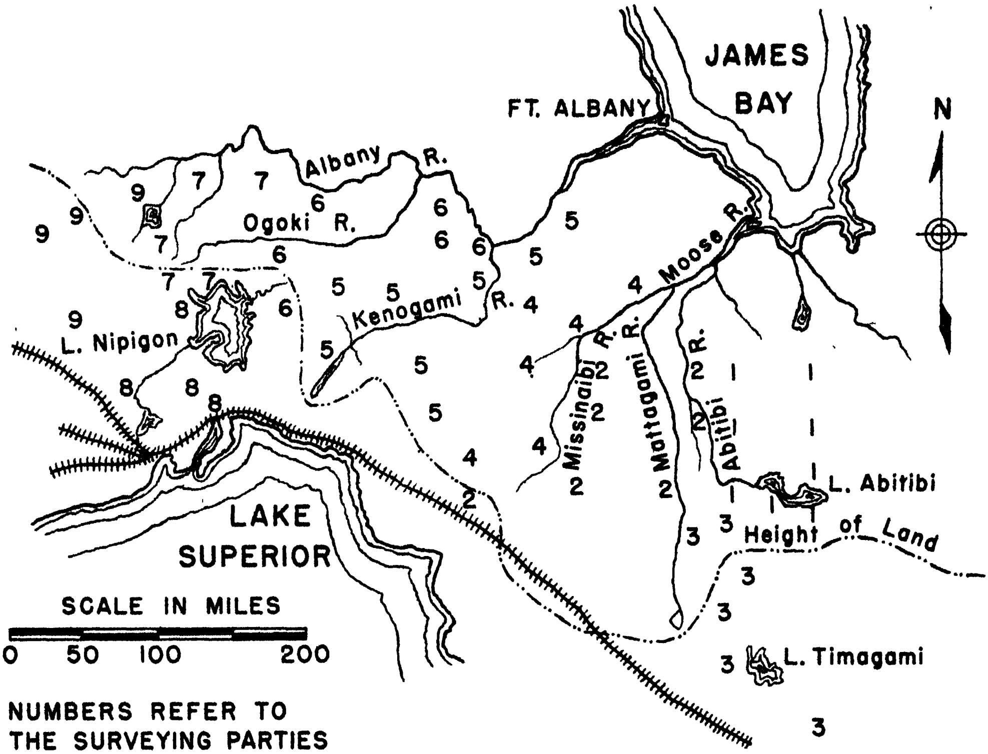

Fig. 10.—Map showing districts explored by surveying parties in northern Ontario in 1900 (from Anonymous 1901). None of the surveying parties reported nesting Canada geese in the districts surveyed.

geese probably do not lie much beyond the coastal strip of country that is underlaid with sedimentary rock, and are not in the adjoining rocky and rugged Canadian shield, is found in the records of 10 surveying parties. In the summer and autumn of 1900, surveys and explorations were made of the natural resources and characteristics of part of northern Ontario by the Ontario Department of Crown Lands (Anonymous 1901). The subject of the survey was a "comparatively unknown part of the District of Nipissing, bounded on the north by the Great Muskeg, adjoining the southern shore of James' Bay." The country, beginning about 80 miles inland from James Bay, was surveyed by districts, an exploring party being assigned to each of 10 districts. The districts that have relation to this study are shown in fig. 10. Each exploring party kept notes on the game conditions in its respective district, and, although a number of kinds of ducks were reported nesting in several of the districts, no nesting Canada geese were noted.

Observations made by Hess (1943) during a plane flight shed additional light on the occurrence of Canada geese southwest from James Bay. His description of the muskeg in that sector could apply to a large portion of the muskeg over the Paleozoic Basin.

> By the time we were in McCausland Township, the country had changed from the poplar and jackpine regeneration on the slopes around the Mattagami River to a vast flat area of muskeg, exactly similar to the country around James Bay. (At this point, we were about 100 miles from the Bay.) Throughout this area, except for a belt of fair-sized spruce along the rivers and larger streams and the bigger lakes, there was no tree growth except dwarf widely-spaced tamaracks and the odd bunch of black spruce trees. The remainder of the area was a greyish yellowish green blanket of moss interspersed in large patches by ripple-like depressions filled with water,

giving a striking similarity to waves of moss and water.

Hess observed only four geese in the area described above. After flying a considerable, but unstated, distance farther, he sighted a chain of five lakes, on one of which were two flocks of geese; "young appeared to be present." Hess reported these lakes as being shallow.

The shores to about 100 feet from the water are ringed by black spruce trees about 30 feet high which shade off a short distance from the lake into the muskeg. The immediate shore was covered by alder and willow and in the far distance the larger spruce trees along the Missinaibi River stood out sharply above the scrub larch and muskeg.

Other Populations.—From the 5,747 Canada geese banded at Horseshoe Lake, only 4 bands have been recovered from the country adjacent to Hudson Bay northwest of Fort Severn, fig. 30. Two of these bands were from geese killed in early spring south of York Factory, apparently in the vicinity of their breeding grounds. Of the more than 16,000 Canada geese banded at the Miner Sanctuary in the autumn, none has been re-

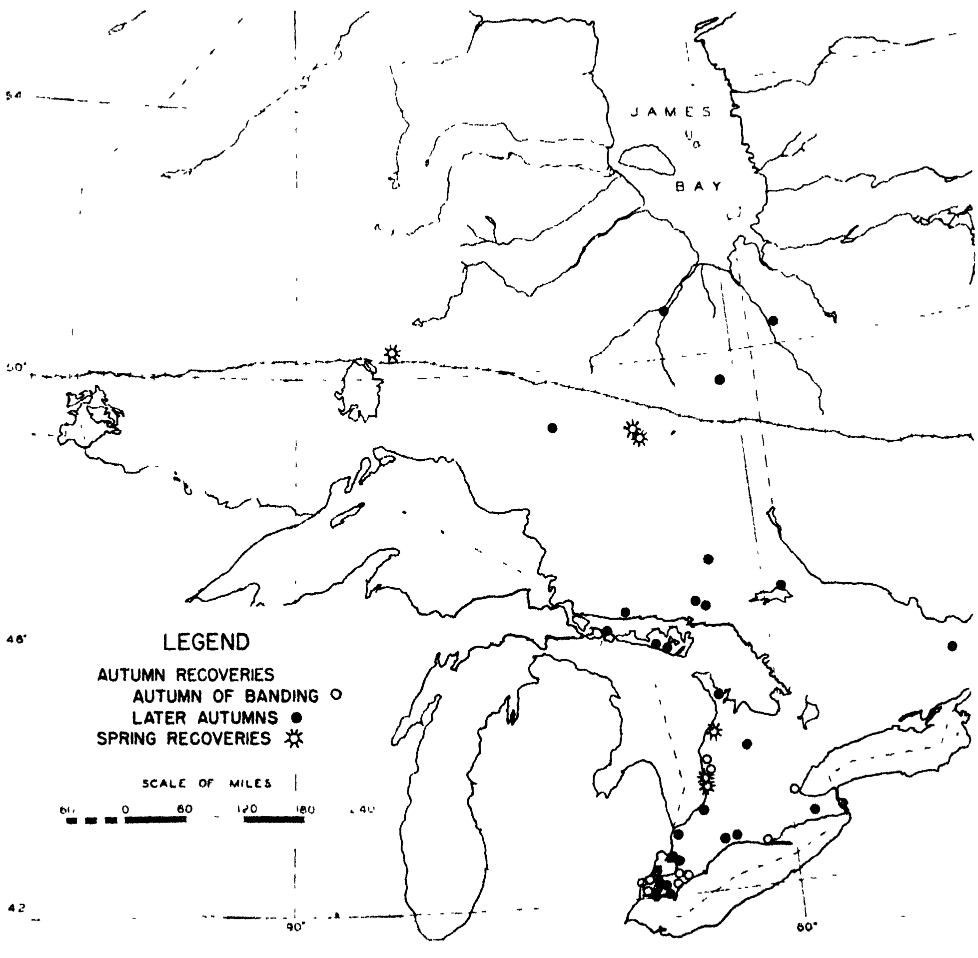

Fig. 11.—Location of band recoveries from Canada geese banded at the Jack Miner Bird Sanctuary in the autumn, 1915–1944, and reported recovered south of James Bay in Canada. Recoveries reported from fur-trade posts on the coasts of Hudson and James bays are indicated in fig. 7. Banding records indicate that two Canada goose populations, the Mississippi Valley and the Southeast, stop at the Miner Sanctuary in the autumn.

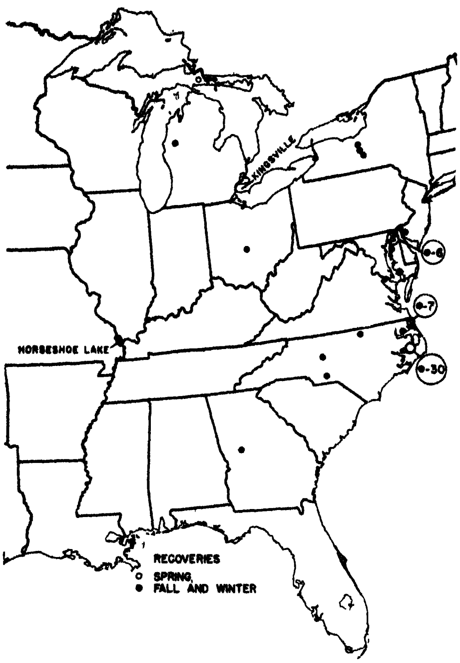

Fig. 12.—Location of band recoveries from Canada geese banded at the Jack Miner Bird Sanctuary, Kingsville, Ontario, in the spring of years prior to 1934 and reported recovered in the United States in the autumn and winter of 1935–36 and (one from a goose found dead) in the spring of 1936.

ported shot north of Lake River, figs. 2 and 7. Hence, it seems probable that most of the muskeg country between Fort Severn and Churchill is occupied by a population of geese that by-pass both the Miner and Horseshoe Lake refuges on their migration to wintering quarters. Miner bands recovered in Canada south of James Bay are indicated in fig. 11. Since few geese banded either at Horseshoe Lake or the Miner Sanctuary have been reported from western Louisiana and eastern Texas, or from any point at an appreciable distance west of the Mississippi River, figs. 12–21, it appears that the western Louisiana flocks, and perhaps a few concentrations in central Missouri, are derived from the breeding grounds between Fort Severn and Churchill. (Fig. 12 shows recoveries of geese banded in the spring; figs. 13–21 show recoveries of geese banded in the fall and winter.) The geese that breed in this part of Canada should probably be included with the Eastern Prairie population, as recently proposed by Cecil S. Williams of the United States Fish and Wildlife Service.

It is apparent from the distribution of the band recoveries shown in figs. 14–21 that two distinct populations of geese are banded at the Miner Sanctuary in the autumn: one population that migrates southwest to winter in the Mississippi River valley; the other, designated as the Southeast population, fig. 6, that crosses the Appalachian Mountains and winters in the inland areas of the South Atlantic states. From the data at hand we can only speculate on the approximate line of demarcation between these two populations on the breeding grounds. Although band recoveries indicate that the breeding grounds of the Mississippi flyway population extend as far south as the Kinoje River, the mouth of which lies 8 miles south of the mouth of the Albany River, between the Kinoje River and the Moose River country there may be a zone of overlap in which is found a mixed popula-

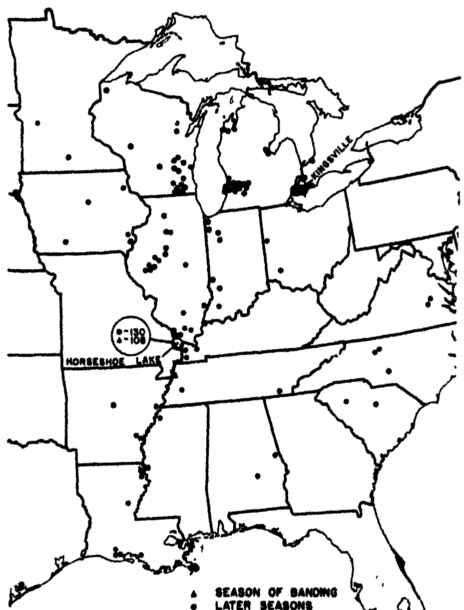

Fig. 13.—Location of band recoveries from Canada geese banded at the Horseshoe Lake Game Refuge and reported recovered in the United States and southern Ontario, 1940–1945. (Missouri recoveries near Horseshoe Lake.)

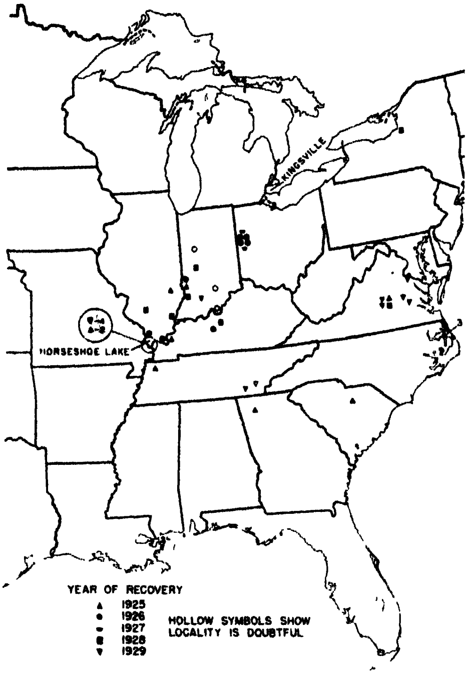

Fig. 14.—Location of band recoveries from Canada geese banded at the Jack Miner Bird Sanctuary during the autumn, 1925–1929, and reported recovered in the United States during the season of banding.

tion of geese, some of which winter in the Mississippi River valley and others that winter in the inland portions of the South Atlantic states.

The principal breeding range of the Southeast population lies inland from the south coast of James Bay. The data available at present suggest that it includes areas drained by the Moose River, as well as suitable muskeg lying between the Moose and Nottaway rivers, and perhaps areas lying inland from the east coast for an indeterminate distance north, fig. 6. Banding records from the Miner Sanctuary show that many of the autumn-banded geese are taken in the spring in the country around the south end of James Bay, fig. 7, and many are taken in the autumn in the inland portions of Virginia, North Carolina, South Carolina, Georgia, Alabama, and the Gulf Coast of Florida, figs. 14–21 (also see Appendix A).

Recoveries from geese banded at the Miner Sanctuary in the spring clearly indicate that the breeding grounds of the flocks that winter along the Atlantic Coast from Maryland to North Carolina, fig. 12, include certain islands in James and Hudson bays (see pages 81–82) and areas inland from the east coast of these bays from about Rupert House to southern Baffin Island, fig. 7.

The large number of band recoveries from the Port Harrison region on the east coast of Hudson Bay, despite low nesting densities reported for that area, may be due in part to the influx of geese in late summer into this lake country, which lies north of the tree line. According to the Reverend H. S. Shepherd, large numbers of Canada geese fly in from the north to the barren-ground lakes for the purpose of moulting. Band recoveries suggest that there may also be an influx of geese that have flown in from considerably south of Port Harrison. No confirmation of this influx was received in the questionnaire distributed in the region; however, A. Lunan of the Hudson's

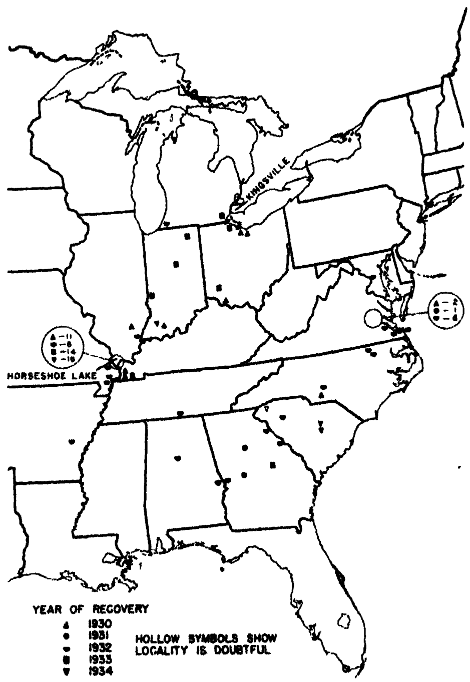

Fig. 15.—Location of band recoveries from Canada geese banded at the Jack Miner Bird Sanctuary during the autumn, 1930–1934, and reported recovered in the United States during the season of banding.

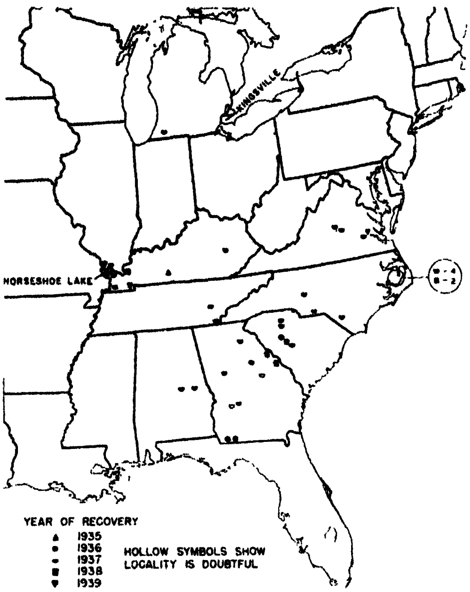

Fig. 16.—Location of band recoveries from Canada geese banded at the Jack Miner Bird Sanctuary during the autumn, 1935–1939, and reported recovered in the United States during the season of banding.

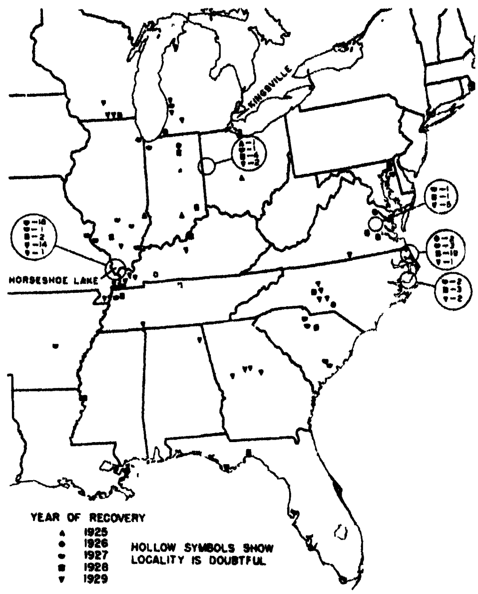

Fig 18.—Location of band recoveries from Canada geese banded at the Jack Miner Bird Sanctuary during the autumn, 1924 or before, and reported recovered in the United States during 1925–1929.

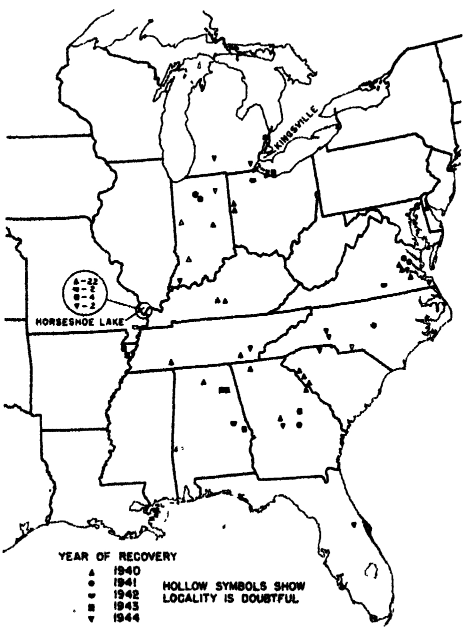

Fig. 17—Location of band recoveries from Canada geese banded at the Jack Miner Bird Sanctuary during the autumn, 1940–1944, and reported recovered in the United States during the season of banding.

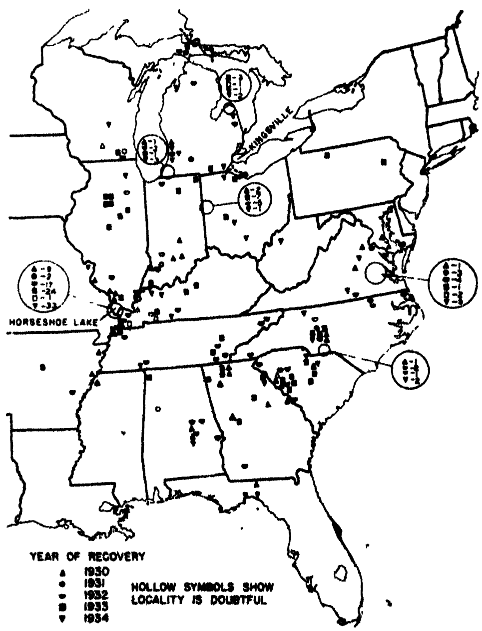

Fig. 19.—Location of band recoveries from Canada geese banded at the Jack Miner Bird Sanctuary during the autumn, 1929 or before, and reported recovered in the United States during 1930–1934.

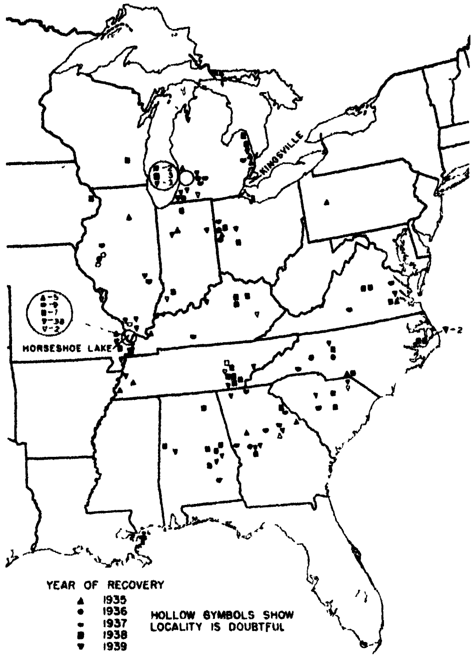

Fig. 20.—Location of band recoveries from Canada geese banded at the Jack Miner Bird Sanctuary during the autumn, 1934 or before, and reported recovered in the United States during 1935–1939.

Bay Company, who was stationed a number of years at Port Harrison, recently stated (personal conversation, August, 1949) that about 75 per cent of the geese killed by the Eskimos in that area were moulting geese that came into the area in early June from the south and not birds that nested locally. His observations thus help to substantiate a relationship that could only be surmised from band recoveries. The Eskimos in the vicinity of Port Harrison, finding other kinds of game less easily obtainable in summer, turn to the inland lakes, where apparently they secure a plentiful supply of flightless geese.

Sixteen recoveries of Canada geese banded at Horseshoe Lake, fig. 30, and an important percentage of the total recoveries of geese banded at the Miner Sanctuary in the autumn, fig. 7, have been made in the Port Harrison district. One or more of a number of possibilities may explain these inconsistencies in the recovery pattern: flights by small groups of Mississippi flyway geese across James and Hudson bays in late summer; northward movements by geese of the Southeast population along the east coast of the bays for the purpose of feeding on berries; actual intermingling of birds from the different flyways. Trapping at the Miner Sanctuary has shown that some of the Horseshoe Lake geese stop at the Sanctuary in the spring, along with the flight of South Atlantic geese. Of 33 Canada geese trapped and banded at Horseshoe Lake and retrapped at the Miner Sanctuary, 1943–1945, 11 were retrapped in the spring. The disposition of some Horseshoe Lake geese to follow the South Atlantic geese to the east coast of Hudson Bay would not be surprising. Recovery of F-marked (autumn banded) birds in the Port Harrison district might be partially explained by the banding of South Atlantic geese at the Miner Sanctuary in the autumn. A certain amount of overlap in migration routes, with the resultant intermixing at the Miner Sanctuary of South Atlantic geese with Southeast and Mississippi flyway birds, is no less to be

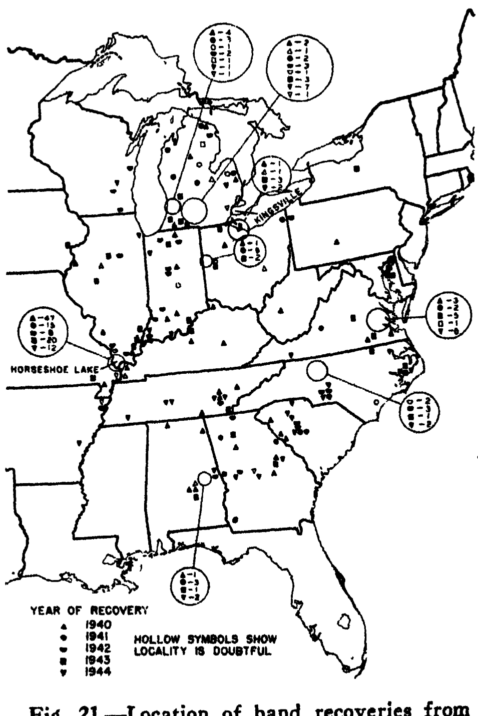

Fig. 21.—Location of band recoveries from Canada geese banded at the Jack Miner Bird Sanctuary during the autumn, 1939 or before, and reported recovered in the United States during 1940–1944.

expected in the autumn than in the spring of the year.

West Coast Muskeg Types

Aerial reconnaissance flights in the region west of James Bay and south of Hudson Bay, fig. 4, revealed that the muskeg in the breeding range of Mississippi Valley Canada geese differs considerably in various sectors in the proportions of timber and water it supports. For the sake of convenience the muskeg can be divided into five main types. It must be remembered, however, that gradations between all types exist.

Type 1. Well-timbered muskeg, with only a few ponds or small, widely scattered lakes, fig. 22.

Type 2. Open muskeg, with treeless or lightly timbered areas of stunted tamarack, alternating with small blocks or extensive stands of black spruce, fig. 23.

Type 3. Lake-land muskeg, relatively well-drained areas, more or less timbered, but notable for the numbers of large, widely scattered lakes without islands, fig. 24.

Type 4. Pothole muskeg, characterized by a myriad of ponds and small lakes, principally from 5 to 30 acres in size and usually possessing one or more islands. These water areas are often so closely grouped that only small patches or narrow strips of land separate one from the other, figs. 25 and 26.

Type 5. "Smallpox" muskeg, that is, muskeg in which sphagnum predominates, the country being more or less a continuous sphagnum bog or series of small bogs in the late stages of filling in so that it can scarcely be classified as land or water, figs. 27 and 28. Fairly extensive areas of this kind occur throughout the Paleozoic Basin and in smaller patches within most areas of the above four types of muskeg.

Aerial observations revealed that the

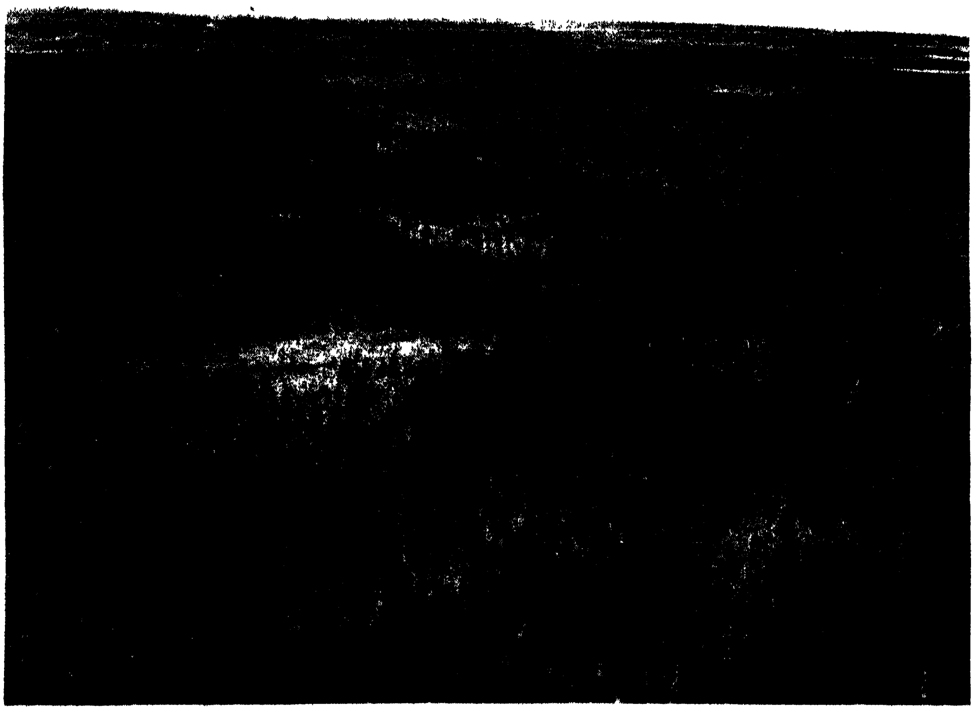

Fig. 22.—Type 1 or well-timbered muskeg. The muskeg lying adjacent to the southern half of the west coast of James Bay is fairly well wooded with black spruce and tamarack. Alternating with the wooded tracts are extensive areas covered with a heavy growth of willow. Ponds and lakes are relatively few in number in this area.

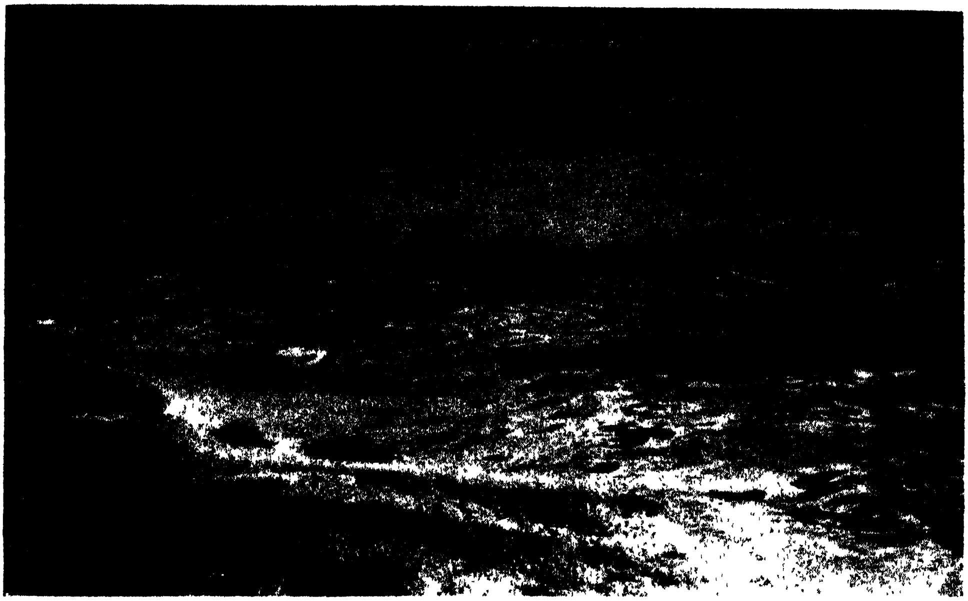

Fig. 23.—Type 2 or open muskeg. The dark bands across the lower half of this illustration represent stands of black spruce; the lighter colored trees are tamaracks. The spruces are confined mainly to better drained sites and to hummocks of mosses and lichens. The tamarack occurs both as light stands on the better drained sites and as scattered, stunted individuals on open sedge areas. In this type of muskeg, the treeless or lightly timbered areas of stunted tamarack alternate with small blocks or extensive stands of black spruce.

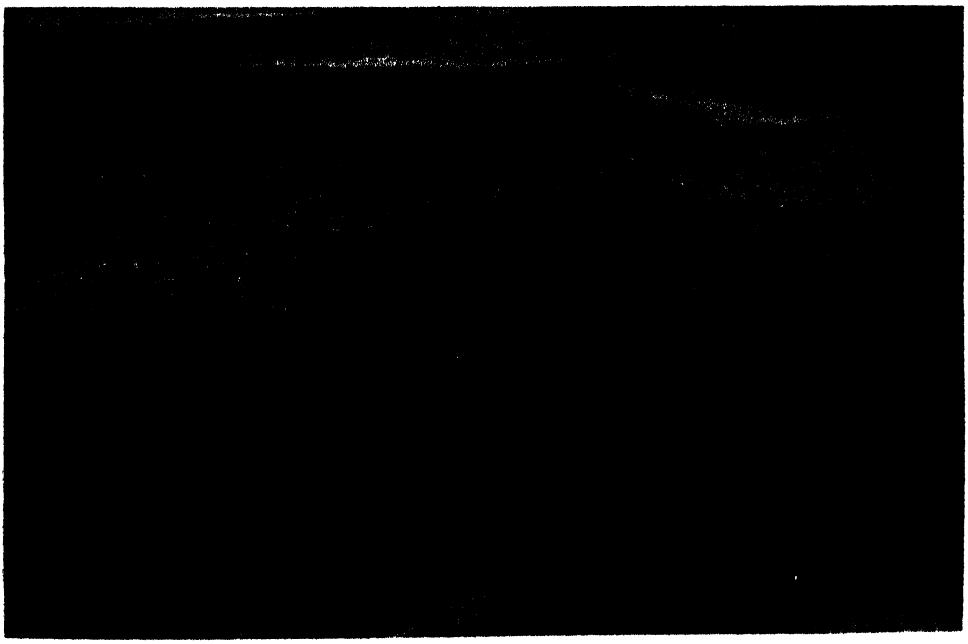

Fig. 24.—Type 3 or lake-land muskeg. Shown here is an area just north of the Albany River (flight I, fig. 4) about 45 miles inland from the coast of James Bay.

Fig. 25.—Type 4 or pothole muskeg. This photograph was taken a few miles north of the Albany River on flight IV, fig. 4.

Fig. 26.—Type 4 or pothole muskeg about 40 miles north of the Moose River and about 30 miles inland from the shore of James Bay.

muskeg for the first 20 to 25 miles inland from the coast of James Bay in the Albany River country, fig. 4, I and III, exclusive of coastal marshes, is chiefly type 1. The muskeg for the next 35 to 40 miles, or about to the longitude of Fishing Creek Island in the Albany River, is characteristically type 4. Most prevalent in the country between Ogoki and points 50 to 60 miles inland from James Bay, fig. 4, I, are types 2 and 3. From Ogoki, on the Albany River, to a point northwest on the Attawapiskat River, fig. 4, II, muskeg types 2 and 3 characterize the country. From this point on the Attawapiskat River to Fort Albany, fig. 4, III, the kinds and the distribution of the muskeg observed are similar, but in reverse sequence to those seen on flight I, fig. 4.

On flight IV, fig. 4, between the Albany River and Weenusk, the following sequence of muskeg types was found to prevail. Type 4 is dominant between the Albany River and the Atikameg River, which lies 15 to 30 miles north of the Albany; types 2 and 3 most of the way between the Atikameg and Kapiskau rivers, north to the Attawapiskat River, and for an additional 10 to 15 miles beyond. Midway between the Attawapiskat and Ekwan rivers the muskeg varies between types 4 and 5. Near the Ekwan River, the country appears to be better drained and timbered, and the muskeg of type 1. From the Ekwan River northward, muskeg types 2 and 3 again prevail, but near the Sutton River, which enters Hudson Bay from the southwest at a point 64 miles west of Cape Henrietta Maria, the muskeg is poorly drained and well supplied with lakes of all sizes. From the Sutton River country to Weenusk the density of the stands of black spruce decreases and the amount of *Cladonia* lichen as ground cover steadily increases; in other respects the muskeg observed in this part of the flight seems to be either type 3 or type 5.

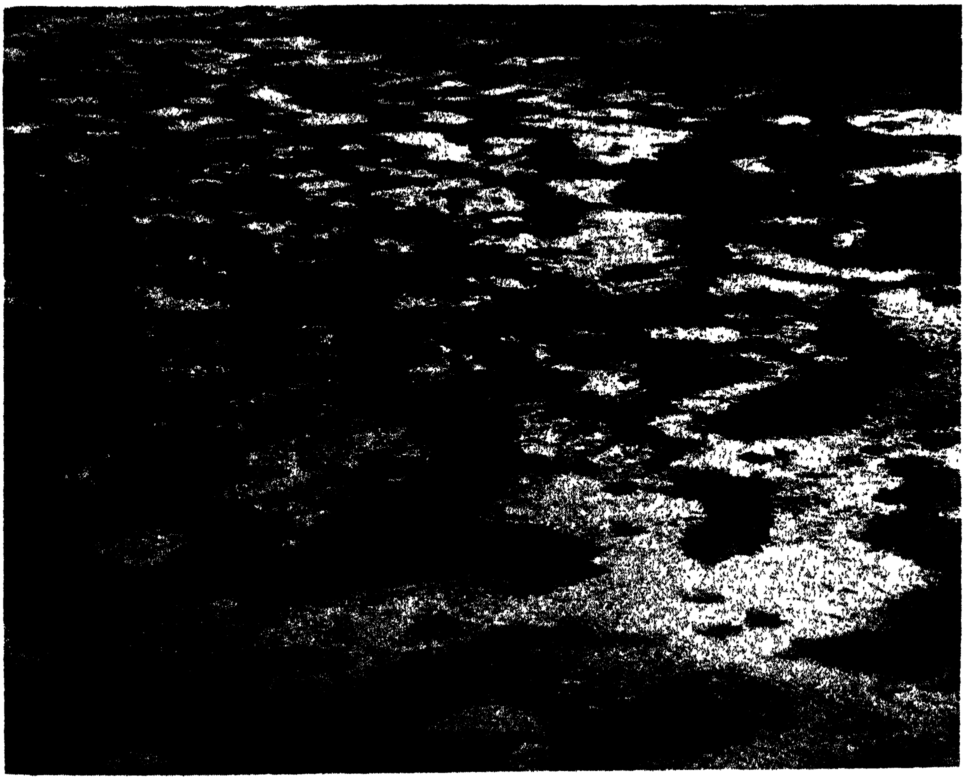

Fig. 27.—Type 5 or "smallpox" muskeg, about 15 miles north of the Attawapiskat River (flight IV, fig. 4).

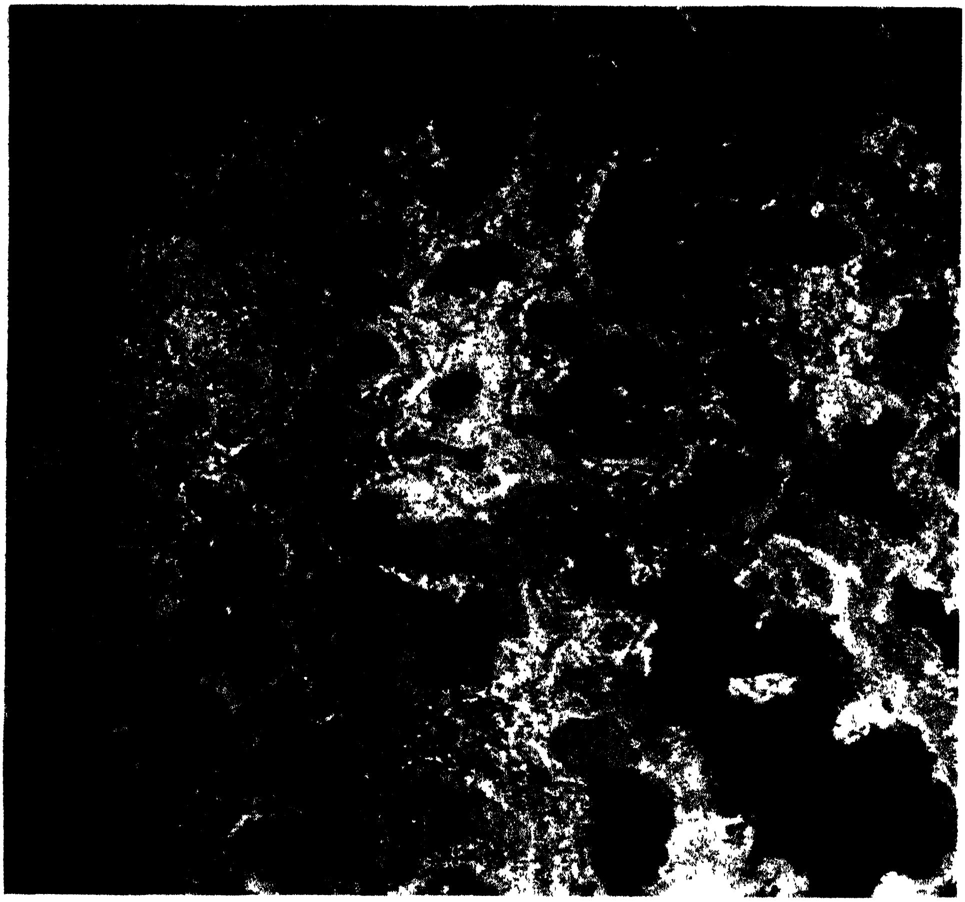

Fig. 28.—Type 5 or "smallpox" muskeg, a vertical aerial view. Small bogs, such as these, in various stages of filling in with sphagnum moss, occupy considerable areas of the muskeg country west of James Bay. They contribute little or nothing to waterfowl production.

Between Weenusk and Fort Severn, fig. 4, VIII, muskeg types 4 and 5 are most common. However, the lakes in this section of the muskeg, some of which are large, do not appear to offer optimum habitat for nesting pairs of geese, as most of them lack islands. The country between Fort Severn and York Factory, fig. 4, VII, appears to be on the whole relatively poor breeding range. In general, the muskeg alternates chiefly between types 3, 4, and 5.

West Coast Production Centers

On the aerial flights outlined in fig. 4, approximately 217 Canada geese, adults and goslings combined, were observed. From these sight observations, from band recovery data given in table 3, the distribution of the various muskeg types, their relation to the configuration of the streams and rivers, and the literature, the existence and location of major production centers, rather than continuous nesting areas, have been deduced. Most of these areas are between two adjacent or converging rivers, similar to the river shown in fig. 29, but in type 4 muskeg.

Most band recoveries and sight observations of geese can be correlated with the distribution of pothole muskeg, type 4. In the majority of areas in which geese were observed, water areas occupied at least 25 per cent of the surface. This muskeg type occupies slight but extensive depressions or troughs in the Paleozoic

Basin, which probably either (1) originated as depressions in the surface of the glacial drift that mantles the region or (2) developed in connection with deposits accumulated during the uplift of the region, probably at an irregular rate, following its submergence during glaciation. These basins now serve as origins of many small streams, while the larger rivers, in seeking the lowest ground when cutting their channels, have tended to converge toward each other in the region of these basins. Consequently, the present-day configuration of the drainage pattern is a clue to the location of pothole muskeg and in turn of production centers for Canada geese.

Available information indicates the following production centers, fig. 30, for the Canada geese that use the Mississippi flyway:

Production Center A. Between the Albany and Attawapiskat rivers in the region of Ogoki and Martin Fall, about 200 miles from the coast of James Bay. Barnston's early report (Richardson 1851) and band recoveries point to the presence of this production center, although it seems to be a relatively unimportant one. The localities mentioned above are just within the western limits of the Paleozoic Basin, figs. 2 and 8. In 1947, the 16 hunters in the Ogoki Indian band were questioned regarding the presence of breeding pairs within their trapping territories. Only a few of the hunters had knowledge of Canada geese nesting in the general region north of Ogoki, and they agreed that breeding pairs were scarce in that sector. A single goose was sighted in this area on flight II, fig. 4.

Production Center B. Between the Atikameg and Albany rivers, from a distance of about 25 miles inland from the coast of James Bay westward to about longitude 82° 50′ or the longitude of Fishing Creek Island in the Albany River. Although the country between the Albany River and the Stooping River, a tributary to the south, was not flown over directly, as much of it as could be seen from the plane appeared to be similiar to the country between the Albany and the Atikameg and equally attractive to nesting geese; probably it should be included as part of the production center. The area

Fig. 29.—The Attawapiskat River, at a point 30 miles inland from the coast of James Bay. Most of the muskeg shown in this photograph is classified as type 2 or open.

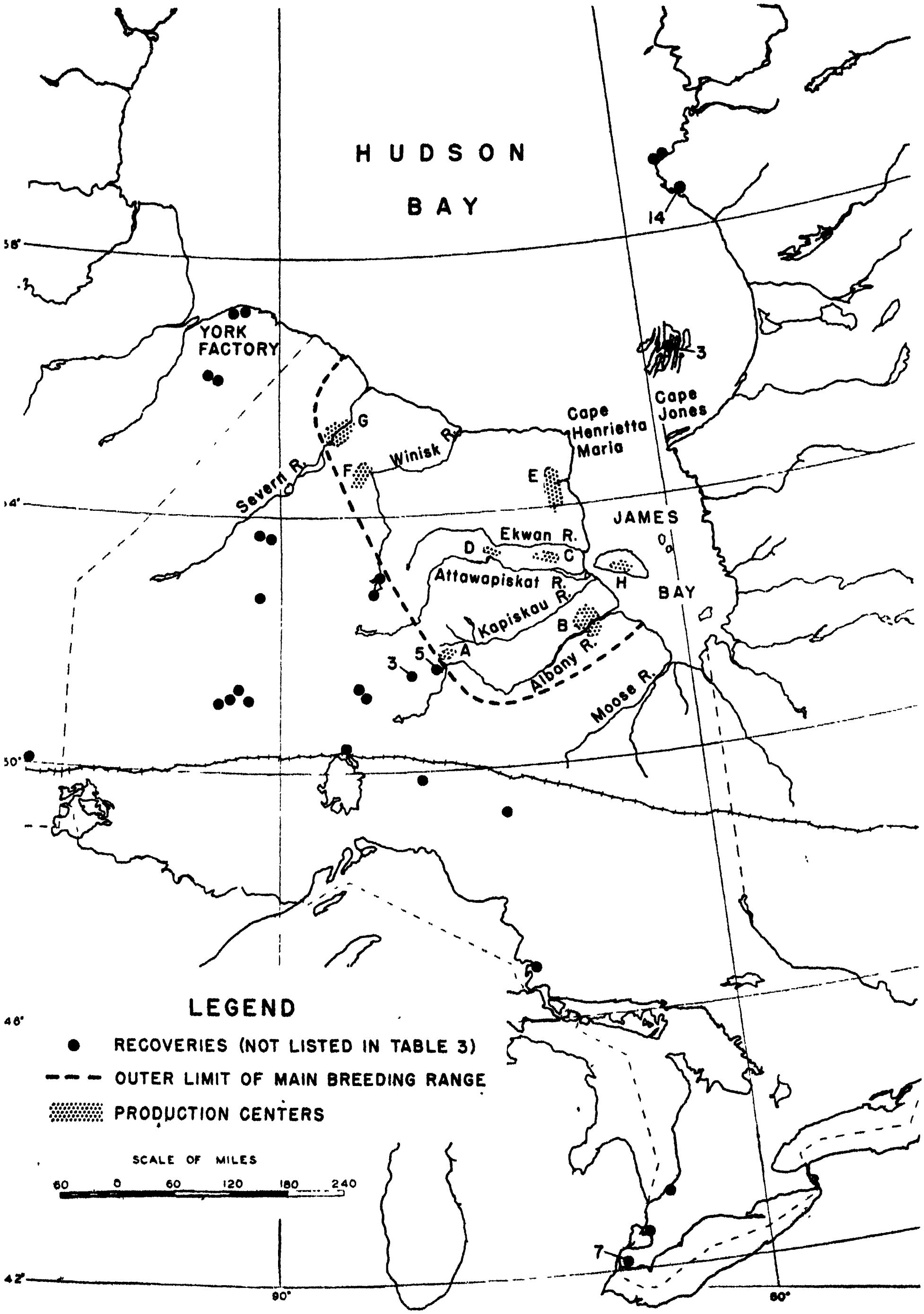

Fig. 30.—Location of production centers, limits of the main range of the Mississippi Valley geese, and located recoveries in Canada, 1941–1947, of Canada geese banded at the Horseshoe Lake Game Refuge. Within the main breeding range 217 band recoveries have been made. (Not shown are one recovery from Warren, Manitoba, and one from McLean, Saskatchewan.)

Fig. 31.—View from the west coast of James Bay about 38 miles south of Lake River. The sinuous tracts of spruce occupy old beach ridges near the coast; the intervening areas are marsh. Many bands were recovered from Canada geese near this part of the coast.

observed, which is characteristically type 4 or pothole muskeg, contained the only geese seen on the east and west flights between Fort Albany and Ogoki. On the return flight, III, fig. 4, 55 adults and 19 goslings were observed. These observations substantiate the location of production center *B* up the Albany River, indicated earlier by band recoveries, table 3.

Field observations and information obtained from Indian hunters indicate that few if any geese nest within 10 miles of the shore of James Bay. The Indians report that very few geese breed in the muskeg close to the bay. Most band recoveries, table 3, from the 9-mile coastal zone probably represent migrating geese shot early in the spring, or wandering, nonbreeding geese.

Despite the fact that some of the Indians from the coastal posts trap and hunt far inland, they have made only a few recoveries of goose bands in the Albany River district more than 60 miles west of James Bay. Substantiating our own finding in the Albany River district, the Indians report that most of the geese breed within 70 miles of the coast, or not much farther west than 30 miles below the juncture of the Albany and Chipie rivers.

Production Center C. Between the Attawapiskat and Ekwan rivers at a distance of between 40 and 50 miles inland from the coast of James Bay. This area was flown over on northward flight IV, fig. 4, from the Albany River to Weenusk. Band recoveries and aerial observations indicate that this area is a relatively unimportant production center. While its extent east and west can only be surmised from band recoveries, aerial observations indicate that its north and south axis is short, approximately 12 miles. Taken as a whole, the potholes and lakes between the Attawapiskat and Ekwan rivers are in a much more ad-

vanced state of filling in than are those between the Atikameg and Stooping rivers and few contain islands. Consequently, they are less attractive to nesting geese. On flight IV, fig. 4, three geese were observed in this production center, and northwest of this center, about 11 miles south of the Sutton River, a single goose was noted.

Production Center D. Between the Attawapiskat and Ekwan rivers, from 90 to 100 miles inland from the coast of James Bay. A production center in this area is suggested by three recoveries, table 3, and some convergence by the two rivers mentioned, as well as by the drainage pattern of the small streams in this area.

Production Center E. South of the barren grounds of Cape Henrietta Maria; from about the latitude of Lake River south to the Swan River and at indeterminate distances inland from the coast of James Bay. The large numbers of recoveries made along the coast in this area, fig. 31, and the multitude of small, short rivers that drain inland areas in this sector suggest that the production center may lie within 15 miles of the James Bay coast. Perhaps indicative of the approximate location of this center is the Kinusheo River, which originates in this region and flows to the northwest to empty into Hudson Bay. When the latest 8-miles to 1-inch maps, based upon high altitude photography carried out in 1947, are completed, the limits of this center will be more easily ascertained.

Production Center F. Between the Winisk River and the Fawn River, at a point about 100 miles inland from the coast of Hudson Bay. In this sector the Winisk River and the Fawn River, the latter a tributary of the Severn River, bow sharply toward each other. Between these rivers a dendritic drainage pattern with a number of poorly defined lakes is shown on an 8-miles to 1-inch Canadian topographic map. At Weenusk, where there are some fairly suitable nesting lakes close to the coast of Hudson Bay, the Indians report that they shoot most of their banded geese, table 3, about 150 miles up the Winisk River in the general region outlined above. The winding of this river accounts for the difference in the two mileage figures given for the location of this production center. Map and band recovery data and the size of the kills made by the Weenusk Indians indicate that this production center is second in importance only to the one between the Atikameg and the Albany or Stooping rivers.

There is probably some scattered nesting over a large area south of Weenusk. On flight IV, fig. 4, two flocks, one of 21 geese and another of 6 with goslings, were sighted about 33 miles south of the Winisk River at a point about 25 miles from the coast of Hudson Bay. On flight VIII, fig. 4, between Fort Severn and Weenusk, 15 Canada geese were observed from the air. However, the lakes flown over on flight VIII did not appear to offer optimum habitat for nesting pairs, as they generally lacked islands. The Weenusk Indians say that they find breeding pairs nesting closer to the coast in early, mild springs than in late, cold springs.

Production Center G. Severn River country. One or perhaps several production centers, poorly defined in either case, may lie in the Severn River country. The configuration of the river and its tributaries and two band recoveries suggest that a production center may be found somewhere between 50 and 90 miles up this river.

William Glennie, a post manager for the Hudson's Bay Company, told the senior author in 1947 that he had seen fresh goose eggs that were taken from nests found in the upper portions of the Severn River watershed, between Windigo and Big Trout Lake, localities that lie just west of the Paleozoic Basin, roughly between latitudes 52° 30′ and 54°, but stated further that the greatest numbers of Canada geese were found along the lower portions of the Severn River.

On flight VII, from York Factory to Fort Severn, a distance of about 145 miles, 28 Canada geese were observed, a number that is indicative of a low population density in this section of the Paleozoic Basin. Observations and aerial photos reveal that the habitat in this area is of relatively poor quality. Many of the water areas are in the late stages of filling in and the great majority of lakes lack islands. Nevertheless, a portion of the muskeg west of Fort Severn probably

Fig. 32.—During the spring and summer the muskeg country is very difficult to traverse on foot. In scene pictured here, small spruce are being put down in order to permit crossing between two mats of floating sedge. The photograph was taken in the Lawapiskau River country on July 3, 1947, at which time ice still could be found in many places 15 inches below the surface of the sedge mat.

should be included in the general breeding range of the Mississippi flyway population because bands have been reported from this country. The breeding density of Canada geese is probably greater than the small number of band recoveries indicate for this section of the muskeg, fig. 30, because of the preference of the Indians at York Factory for hunting other kinds of geese on the coast of Hudson Bay: Richardson's goose *(Branta hutchinsii)* and the lesser snow goose *(Chen h. hyperborea)*, species said to be fat both in the spring and in the autumn, while the Canada goose is reported to be thin and unpalatable when it arrives on the interior breeding grounds.

Production Center H. Akimiski Island. From the accounts of the Indians at Attawapiskat and observations made from the air, nesting on Akimiski Island is found chiefly in the central portion close to the south coast. In this area many suitable lakes were seen and 61 geese were observed on the 1947 flight.

Nest Sites

Although there are a number of fairly well-defined centers of production where most of the geese nest and rear their young, aerial flights in 1947, fig. 4, substantiated the information gathered earlier from the Indians that the breeding pairs are scattered within these centers; there is seldom more than one pair on a given lake. Further evidence pointing to scattered nesting was gained by the senior author in 1947 when traversing the muskeg on foot. A few penetrations of the muskeg were made at points 15 and 25

Fig. 33.—Typical type 4 muskeg lake with small islands. According to native Indians, small islands in lakes of this kind offer preferred nesting sites to Canada geese.

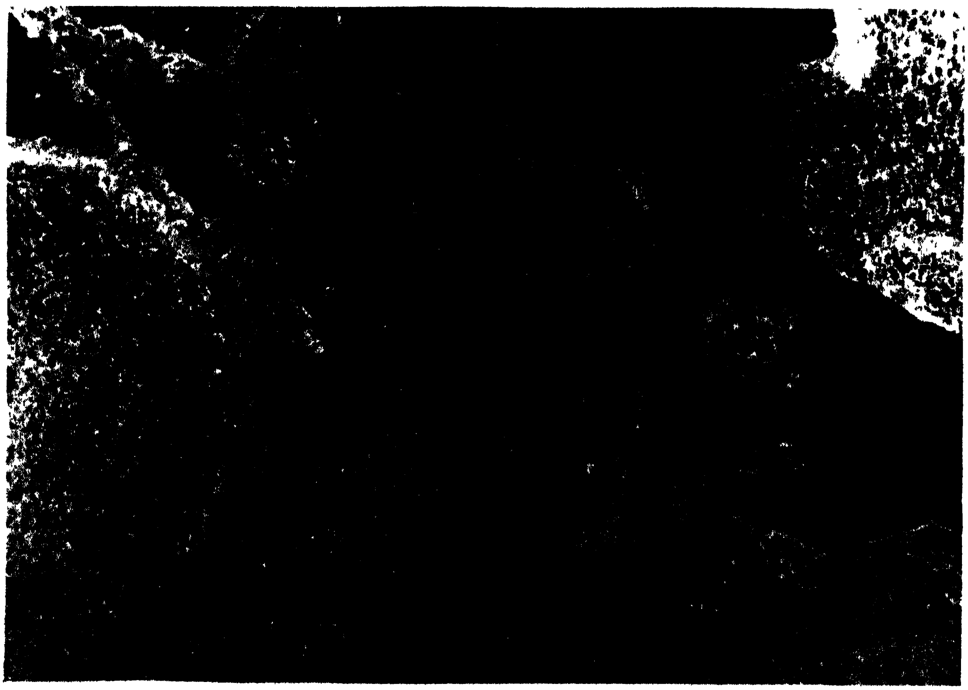

Fig. 34.—Vertical view of type 4 or pothole muskeg. Extending outward from most stands of trees is a floating mat of sedge partially supported by sphagnum moss.

miles up the Lawapiskau River, reportedly goose-nesting country, and at two points 40 miles up the Albany River, which the aerial flights a few days before had revealed as production centers. During these walks, only one pair of geese was observed, but the faint trails of several broods were found, revealing where geese had moved from one small muskeg lake to another.

Unfortunately, because the breeding pairs were scattered and the nesting habitat was highly inaccessible, both from the standpoint of getting a canoe within walking distance of a production center and of actually traversing it on foot, fig. 32, no nests were located in 1947. According to the Indians, small islands in lakes and ponds offer preferred nesting sites, figs. 33 and 34, but, where no islands are present, nearly any location close to the water's edge is suitable. An impression gained from the aerial survey is that small lakes of 5 to 30 acres in size and possessing one or more small islands are the type preferred by nesting pairs.

In the western United States, Canada geese have been found by wildlife workers to concentrate in favored sections of a marsh or breeding range, such as particular islands in lakes and reservoirs. As a result of such colonial-type nesting, young broods of several pairs frequently combine into a large rearing brood, a single pair eventually taking charge of this brood. The fact that only families of normal size have been observed at Horseshoe Lake, or have been reported by Jack Miner at Kingsville (see section on "Productivity"), suggests that scattered nesting is the rule in the muskeg west of James Bay; the assumption is that nesting pairs are so spaced that contacts between broods are infrequent and combination does not take place to an important degree.

Information corroborating this viewpoint was reported by R. M. Duncan and A. H. Michell. Both of these men have spent many years as post managers on the east and west coasts of James Bay. They report that the autumn migration of Canada geese along the west coast is primarily that of small family flocks, observations which are in agreement with those made by the authors. On the east coast, according to Duncan and Michell, flocks of from 20 to 40 or more geese generally comprise the autumn flight. However, the presence of large flocks in the autumn along this coast of James Bay is not surprising since areas of favorable habitat are more limited there and the density of nesting pairs is relatively high, particularly on the Belcher and Twin islands. Donald F. Coates and Donald B. Coombs, as cited earlier (personal communication, 1947), found 6 adults and 21 goslings together on Weston Island. From these reports it would seem that in the Hudson and James bay region, as in western United States, crowding of the nesting pairs is a factor likely to induce the combining of broods.

MIGRATION

The beautiful and often spectacular flights of the Canada goose have probably held a greater fascination for more people than the flights of any of our other native birds. Some persons think of geese in flight as special creations, living enviable and unfettered lives. Other persons thrill to the sight of migrating geese as an object of sport. To the Canadian Indian trapping in the "bush," the first flocks of geese in early spring afford a welcome opportunity for a change of diet from bannock, beans, and dried or salted meats. In years when fur and game animals are at low points of their cycles, and consequently food stocks are close to depletion, the arrival of geese may mean relief from near starvation.

Autumn Migration Routes

Our data on the movements of the Canada goose in the Hudson-James bay area are based on information received from the Indians and white residents and on personal observations. Band recoveries have been the principal source of information relating to autumn migration movements of Canada geese in the United States, figs. 13–21, but these recoveries do not furnish a complete picture of the migration routes. Naturally, most recoveries are from localities where hunters as well as geese congregate, generally in the vicinity of favorite waterfowl rest lakes or feeding areas where the flocks linger before continuing south. Wooded

or hilly country and waterless prairies are usually flown over nonstop by migrating geese. Consequently, very few bands have been recovered from country of this nature, even though large numbers of geese pass overhead each autumn and spring.

Fig. 35.—The tundra of the Cape Henrietta Maria area as seen from the air.

Fig. 36.—The mouth of the Moose River and a portion of Ship Sands Island. The extensive marshes shown in this scene are heavily used by blue and snow geese and to a lesser extent by Canada geese in the autumn.

In Canada.—Before the southward migration from the breeding grounds takes place, a rather complex series of local flights occurs. About August 15, shortly after the young birds are on the wing, a movement begins to the coasts of Hudson and James bays. This is not a mass flight but a movement of family groups and small flocks from some of the production centers near the coast. The geese that have nested adjacent to the southwest coast of Hudson Bay fly north to the coast and then almost due east to Cape Henrietta Maria, figs. 2, 30 and 35; those that nested adjacent to the west coast of James Bay, north of the Ekwan River, fly east to the coast and then north to Cape Henrietta Maria. This cape is an isolated area of tundra attractive to the geese at this season because of the abundance there of blueberries (*Vaccinium* sp.), billberries (*Vaccinium uliginosum*), dwarf raspberries (*Rubus arcticus*), and crowberries (*Empetrum nigrum*). It is of interest to note here that flights to the sea coasts for the purpose of feeding on berries and other foods have been reported for other Canada goose populations in the north country [Newfoundland (Howley 1884); northern Ungava (Bent 1925, quoting Lucien M. Turner); and Labrador (Austin 1932)].

The geese that concentrate on the tundra of Cape Henrietta Maria remain there for varying periods before flying south. The length of time the geese remain in this region depends to a large degree upon the success of the berry crop, but probably all geese leave the cape by the latter part of September. At least half of the "cape geese," as they fly south down the west coast of James Bay, stop at Akimiski Island, where they concentrate on the wide flat marsh on the north side, a favorite feeding area. According to A. H. Michell of the Hudson's Bay Company, this flight usually takes place about September 15.

Most of the geese nesting south of the Ekwan River remain in the interior, although a few of them fly to James Bay, where they congregate in moderate-sized flocks in the coastal marshes about the river mouths, in country similiar to that shown in fig. 36; others continue to the marshes of Akimiski Island.

Apparently, many of the geese that feed on Akimiski Island fly directly to the Jack Miner Sanctuary as soon as they leave the island. The Indians at Fort Albany claim that since Jack Miner started banding geese at his sanctuary they have killed only a few in the autumn.

A number of bands from geese banded at Horseshoe Lake have been recovered in summer from the Belcher Islands and the east coast of Hudson Bay in the region of Port Harrison, fig. 30. Whether these bands have been recovered from South Atlantic geese that strayed from their normal flyway and were banded at Horseshoe Lake, whether they were recovered from Mississippi flyway geese that strayed east of their normal flyway on their spring migration, or whether they were recovered from Mississippi flyway geese that nested west of James Bay and then struck out across the bays can be only conjectured on the basis of available data. In any case, many geese that are on the east coast of Hudson Bay in autumn migrate southward along the coast to the south end of James Bay, where they converge with the groups that have flown south along the west coast of James Bay.

Because band recoveries suggest a northward movement along the east coast of James and Hudson bays in the early autumn by geese that have nested inland from the south coast of James Bay, we believe that the final southward flights along the east coast of both bays may consist of at least some geese from three different populations. Geese of the South Atlantic population that nested along the east coast and on neighboring islands (Belcher and others) make up most of the flight; geese of the Southeast population probably are second in numbers; while individuals of the Mississippi Valley population are least numerous, fig. 7.

At points near the south end of James Bay, the South Atlantic geese split away from the Mississippi Valley and Southeast populations; portions of only the last two populations migrate through the Kingsville region in the autumn. The apparent mechanism of the splitting off of the southward flights along the east coast of James Bay into their various components, fig. 37, has been deduced

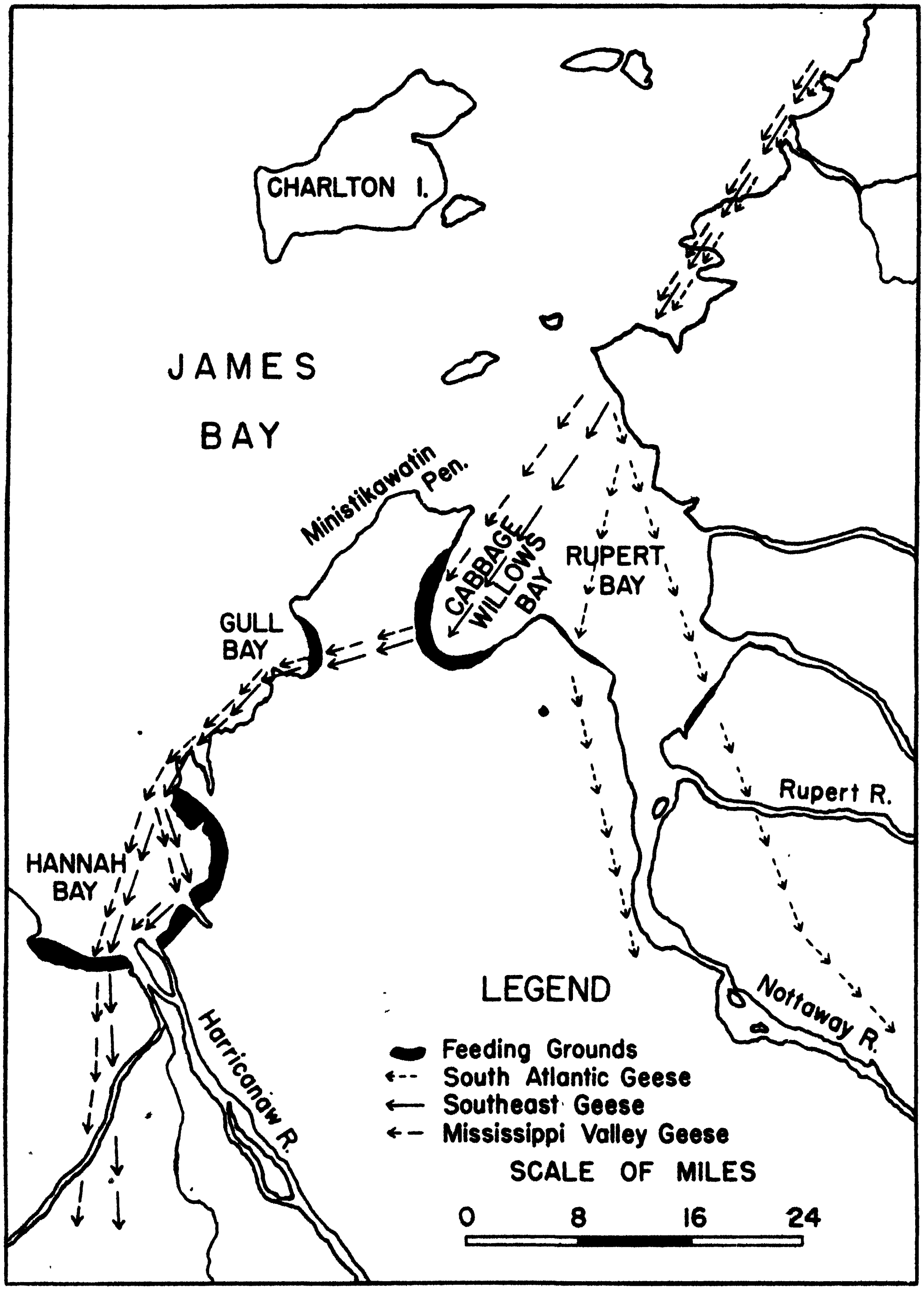

Fig. 37.—Probable migration routes taken by various populations of Canada geese at the southeast end of James Bay. The first splitting away from the combined flocks that migrate southward down the east coast of James Bay occurs somewhere along the northeast shore of Rupert Bay. A second splitting away occurs at or near the feeding grounds bordering Cabbage Willows Bay, the Mississippi Valley geese flying southward, the South Atlantic geese toward the southeast.

from a description of goose flights in the Rupert House area given to us by A. H. Michell, post manager at Rupert House.

The first splitting off of the combined autumn flights evidently occurs somewhere along the northeast shore of Rupert Bay, fig. 37. Some of the birds follow the northeast shore of Rupert Bay to the coastal marshes near the mouth of the Rupert River, where they congregate and feed; then they leave the James Bay region and fly southeast. Other flights cross Rupert Bay and feed in the marshes in the vicinity of Cabbage Willows Bay. At this point a second split occurs; some of the geese fly southeast, while the remainder follow a natural pass along a small stream and a series of muskeg lakes across the neck of the Ministikawatin Peninsula. These birds continue on to Hannah Bay, where they find final feeding grounds before departing from the James Bay region.

The geese that have remained in the muskeg west of James Bay, instead of flying to the coastal marshes, migrate south on a broad front, crossing into upper Michigan, Wisconsin, and eastern Minnesota, fig. 13. Probably they comprise the majority of the birds in the Mississippi Valley population, figs. 13–21.

In the United States.—Band recoveries indicate that the flights of Canada geese that enter the United States by way of upper Michigan, Wisconsin, and eastern Minnesota constitute the bulk of the Mississippi Valley population figs. 13–21. The flocks that migrate through Wisconsin in the autumn adhere principally to the eastern half of the state. Many of the flocks follow the west shore of Lake Michigan. Other flocks favor one of two other routes: (1) the valley of the Wisconsin River; (2) from Green Bay south to Lake Winnebago, the flights probably splitting south of Lake Winnebago, one sector going to the Lake Geneva area and the other following the Rock River.

According to Zimmerman (1943), the greatest concentration of Canada geese in Wisconsin during the autumn migration occurs in Adams, Columbia, Fond-du-Lac, Sauk, Walworth, and Waushara counties; the Arlington prairie in Columbia County and the Rock and Big Foot prairies in Walworth County attract the greatest numbers. At the peak of the flight in 1941, about November 15, it was estimated that 15,000 to 20,000 geese were using Lake Wisconsin (Zimmerman 1942). Five thousand of these birds fed in the cornfields in the vicinity of Sumpter, Sauk County (Zimmerman 1942).

Appreciable numbers of Canada geese follow the west shore of Lake Michigan south, according to A. B. McDonald of Wadsworth, Illinois, who reported to Frank C. Bellrose of the Illinois Natural History Survey that each year flocks of Canada geese follow the shore line as far south as Zion, Illinois, at which point they leave the lake and fly southwestward. The exact route taken each year is said to remain identical.

The Canada geese entering the United States from the Miner Sanctuary by way of southeastern Michigan or northwestern Ohio constitute a part of the Mississippi Valley population. Recoveries of geese banded in the autumn at the Miner Sanctuary show that this segment of the Mississippi flyway population migrates almost straight southwest to the Ohio or lower Wabash rivers, stopping en route in considerable numbers at Lake St. Mary or Grand Reservoir, a 17,500-acre impoundment lying in Mercer and Auglaize counties, western Ohio. On leaving Lake St. Mary this group seemingly flies directly to the Ohio River valley, which it follows to Horseshoe Lake.

Another group of geese appears to migrate across lower Michigan from Saginaw Bay to the counties in the southwestern portion of the state. Some of these geese winter in the vicinity of the W. K. Kellogg Bird Sanctuary near Gull Lake, Kalamazoo County, and along the lower Kalamazoo River. The majority eventually continue southward, crossing north-central Indiana to the Wabash River bottoms; some of them join geese that have migrated south along the east shore of Lake Michigan and then fly either straight south to the Wabash and Ohio river bottoms or in smaller numbers fly southwestward directly to Horseshoe Lake.

Much of the Canada goose flight entering Illinois from Wisconsin in all likelihood traverses the length of Illinois on a fairly broad front, but band recoveries

Table 4.—Canada geese banded at the Horseshoe Lake Game Refuge and recovered in the United States away from Horseshoe Lake, seasons of 1940–41 through 1945–46.

Season of Banding	Total Geese Banded	Early Banding[1]	Hunting Season			Hunting Season of Recovery and Direction of Recovery from Horseshoe Lake																	
			Northern Zone	Central Zone	Southern Zone	Season of Banding			First Season After Banding			Second Season After Banding			Third Season After Banding			Fourth Season After Banding			Fifth Season After Banding		
						South[2]	East[3]	North[4]	South[2]	East[3]	North[4]	South[2]	East[3]	North[4]	South[2]	East[3]	North[4]	South[2]	East[3]	North[4]	South[2]	East[3]	North[4]
1940–41....	315	0	10/1–11/29	10/16–12/14	11/2–12/31	0	0	0	3	0	7	1	2	1	0	0	5	0	1	2	0	0	2
1941–42	402	0	10/1–11/29	10/16–12/14	11/2–1/10	0	0	0	3	1	2	0	0	6	1	0	1	0	0	0			
1942–43...	1,036	443	9/26–12/4	10/15–12/13	11/2–1/10	0	0	0	5	1	4	2	2	4	0	1	5						
1943–44...	2,329	2,095	9/25–12/3	10/15–12/13	11/2–1/10	1	0	0	4	4	7	2	0	20									
1944–45...	853	651	9/20–12/8	10/14–12/12	11/2–1/20	0	0	0	0	0	10												
1945–46..	310	302	9/20–12/8	10/14–1/1	11/2–1/20	0	0	0															
Total	*5,247*	*3,491*				*1*	*0*	*0*	*15*	*6*	*30*	*5*	*4*	*31*	*1*	*1*	*11*	*0*	*1*	*2*	*0*	*0*	*2*

[1] Number of geese banded in fall up to 2 days before close of hunting in Southern Zone.
[2] Lower Mississippi River valley and coastal marshes of Louisiana.
[3] Southeast states, Virginia to Alabama.
[4] Sections of the Mississippi flyway north of the normal winter range of the Horseshoe Lake flock.

suggest that important numbers of birds follow the Illinois River to its juncture with the Mississippi River. At that point the Illinois River flight may be augmented by flocks (relatively few in number) that follow the Mississippi River southward toward Horseshoe Lake.

Because there has not been sufficient banding of Canada geese in southern parts of the Mississippi flyway, the flight lanes of Canada geese wintering on the lower Mississippi River, from Tennessee to Louisiana, are less apparent than the routes taken by flocks wintering farther north. Recoveries of geese banded at Kingsville, Ontario, in the autumn, figs. 14–21, suggest that many of the flocks migrate down the lower Ohio River valley to the Tennessee River, which they follow south instead of continuing on to Horseshoe Lake. Presumably, at a number of points these flocks later leave the Tennessee River and cross over to the lower Mississippi River.

Additional data indicating that considerable numbers of geese by-pass Horseshoe Lake to the east via the Tennessee River are found from band recoveries of geese raised at Seney National Wildlife Refuge in the northern peninsula of Michigan, fig. 39*K*. Of the total number of band recoveries made, the number reported from Arkansas was second only to the number reported from Michigan (Johnson 1947). These recoveries were made during the same period that heavy kills were occurring at Horseshoe Lake. It is, of course, assumed that the migrant birds from the Seney Refuge joined other wild flocks from the north or at least used the traditional paths of migration.

Recently Earl L. Atwood, manager of the Kentucky Woodlands National Wildlife Refuge, informed the senior author (personal communication, December, 1947) that the Tennessee River valley is a traditional flyway for Canada geese.

There is no evidence, either from observation or from band recoveries, to indicate that there is an important turnover in the flock using the Horseshoe Lake area in the autumn. According to our records, only one goose banded at the refuge has been taken an appreciable distance south of it the same season as banded, fig. 13 and table 4. If a turnover in the flock occurs, it must be early in the autumn before many geese have been banded.

There is reason to believe that the Horseshoe Lake Refuge has acted as a "bottleneck" in that each year it has attracted increasing numbers of geese that previously have wintered along the lower Mississippi River. Few of these geese, having entered the refuge, would be expected to continue migration later in the season, except under pressure of extreme weather. Hence, they would augment the concentration surviving from previous years as well as contribute to the kill. The theory that the refuge acts as a "bottleneck" assumes that ingress of new birds from other areas exceeds the egress of old flock members. The decoying effect of a large concentration, abundant food, and a roost lake would seem the basis for a differential in favor of ingress.

We do not yet have satisfactory data on the migration routes of Canada geese wintering in western Louisiana. Recovery records of geese banded at the Miner Sanctuary and at Horseshoe Lake indicate that the migration routes of the Mississippi Valley population do not lie far west of the Mississippi River. Hence, the flocks that migrate through central or western Minnesota, Iowa, Missouri, and Arkansas, and those (possibly the same) that winter in western Louisiana, constitute part of a distinct population, the Eastern Prairie, but scattered band recoveries of geese banded at Horseshoe Lake and taken in Manitoba, South Dakota, western Minnesota, Louisiana, and eastern Texas are evidence that there is some exchange of birds between the Mississippi Valley population and the Eastern Prairie population.

Spring Migration Routes

There are too few spring band recoveries in the United States to depict accurately the northward migration routes of Mississippi flyway geese. Judged by trap records from the Miner Sanctuary, the spring movement is more directly northward and somewhat west of the autumn migration routes. Each spring in early March, a marked increase is noted in the numbers of Canada geese at Horseshoe Lake and at Hovey Lake, Posey County, Indiana. The latter area

harbors few geese in the autumn, but is host to large concentrations after the middle of February. It is conceivable that the late winter concentration may consist of geese of the Southeast population, which may take a more westerly route in their northward than in their southward migrations. Other important late winter or spring concentration points are the drainage districts near Putnam, Illinois (spring 1946 and 1947), the Horicon National Wildlife Refuge (Hopkins 1947), bottomlands of the Bark River in Wisconsin, farm lands at the south end of Lake Oshkosh in eastern Wisconsin, and Gull Lake in southwestern Michigan.

As most spring band recoveries are from the remains of geese shot the previous autumn, no differentiation is made between autumn and spring recoveries in figs. 13–21.

Apparently, after feeding in the rich farm lands along the migration routes in the United States and southern Canada, the flocks fly almost directly to the breeding grounds.

Time and Rate of Migrations

The autumn migration of geese wintering at Horseshoe Lake is spread out over at least a 3-month period, the earliest migrants leaving James Bay in the forepart of September and the last reaching Horseshoe Lake in December, the exact dates depending on the severity of the weather.

Migration records from federal refuges and Horseshoe Lake, table 5, suggest that the outward movement of geese from the breeding grounds may be compared with a segment of the concentric waves produced by an object striking the surface of a body of water; the earliest flocks or migratory waves travel the greatest distances in the shortest periods of time and reach their wintering grounds in the far south before many other flocks have left the north country. First arrivals are noted at Horseshoe Lake and at federal refuges farther south as early as or earlier than they are recorded at refuges farther north. A similar picture has been found to be true for areas lying only short distances apart. Leopold & Jones (1947) reported that in 5 out of 6 years flocks of Canada geese were recorded near Madison, in Dane County, Wisconsin, 2 to 27 days before they were observed about 40 miles to the northwest, near the Wisconsin River, in Sauk County.

Table 5.—Dates of first recorded autumn arrivals of Canada geese at federal refuges and at Horseshoe Lake, Illinois, 1938–1944.

Refuge	Degrees North Latitude	Dates of First Arrival							Average Arrival Date
		1938	1939	1940	1941	1942	1943	1944	
Rice Lake, Minnesota..	47	—	10/12	10/26	10/15	—	10/6	10/1	10/10
Necedah, Wisconsin	44	—	10/20	10/12	10/8	10/8	—	—	10/12
Union Slough, Iowa .	43	—	—	—	—	—	10/15	10/20	10/17
Upper Mississippi	See footnotes	10/22[1]	—	10/13[2]	10/8[3]	10/9[4]	—	9/23[1]	10/9
Squaw Creek, Missouri.	40	—	9/24	10/15	—	10/4	—	10/10	10/6
Swan Lake, Missouri ...	40	10/14	10/4	10/4	10/10	10/11	9/17	—	10/5
Horseshoe Lake, Illinois....	37	—	—	—	9/10	9/21	10/1	9/24	9/22
Kentucky Woodlands (Gilbertsville Reservoir)..	37	—	—	—	10/28	12/31	10/26	11/5	11/14
Reelfoot Lake, Tennessee ..	36	—	—	—	—	9/27	9/12	9/8	9/16
Wheeler, Alabama.........	35	—	11/4	10/8	10/18	12/8	11/2	11/4	11/2
White River, Arkansas....	34	10/19	10/17	—	10/1	9/27	9/25	10/1	10/5
Lacassine, Louisiana.....	30	—	9/28	10/12	12/21	—	10/1	9/2	10/1
Sabine, Louisiana	30	10/20	10/14	9/27	9/25	9/12	10/30	10/5	10/6
Delta, Louisiana	29	—	10/27	10/6	—	10/18	10/26	10/25	10/20

[1] Section of refuge unknown.
[2] Savanna, Illinois, District, 42° N. Latitude.
[3] Guttenberg, Iowa, District, 43° N. Latitude.
[4] Bellevue, Iowa, District, 42° N. Latitude.

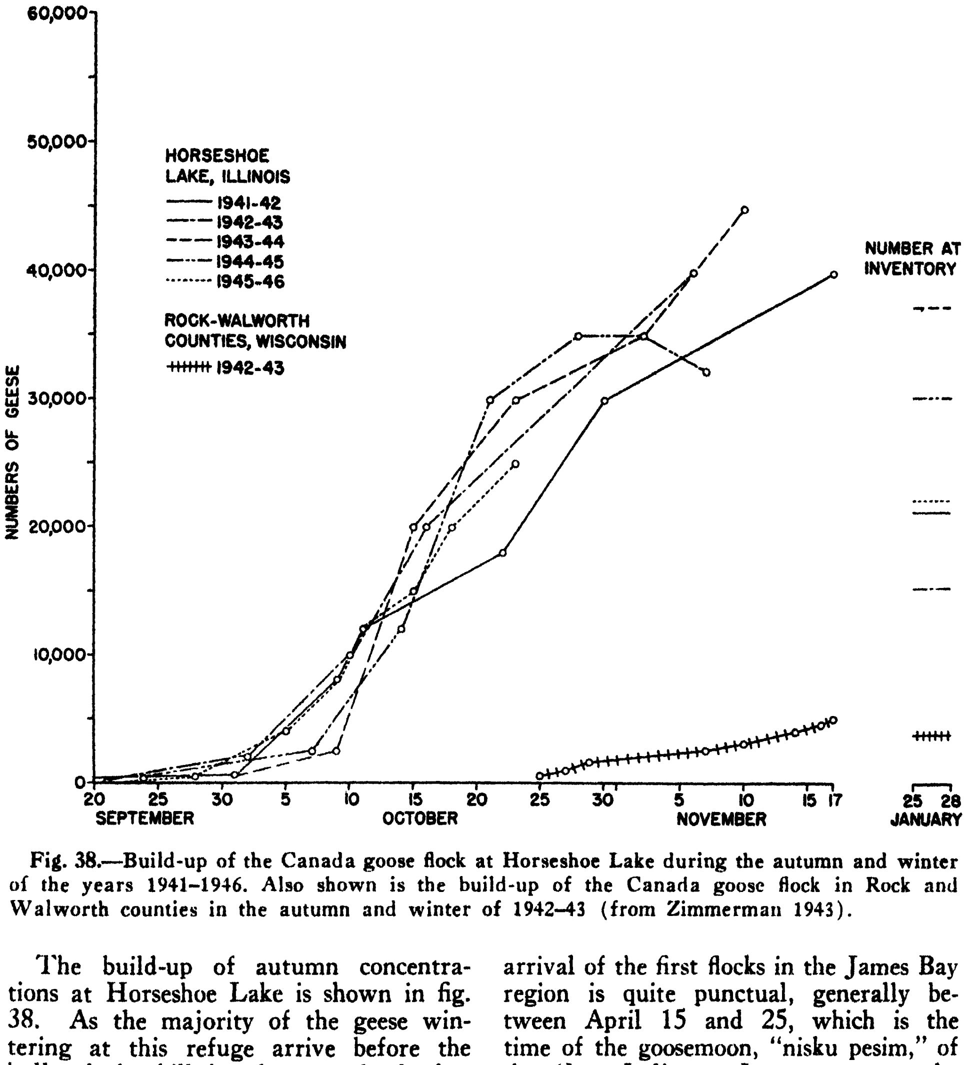

Fig. 38.—Build-up of the Canada goose flock at Horseshoe Lake during the autumn and winter of the years 1941–1946. Also shown is the build-up of the Canada goose flock in Rock and Walworth counties in the autumn and winter of 1942–43 (from Zimmerman 1943).

The build-up of autumn concentrations at Horseshoe Lake is shown in fig. 38. As the majority of the geese wintering at this refuge arrive before the bulk of the kill has been made farther north, probably the flocks that leave the breeding grounds later, and winter farther north, contribute most to the kill in areas north of the refuge.

Spring migration movements appear to be more leisurely than the flight south, but this impression may be created by flocks of nonbreeding adult or yearling geese that are under no stimulus to reach the breeding grounds at an early date. We have seen several hundred geese in the vicinity of Lake Wisconsin throughout the first week in May, and Hopkins (1947) states that the last flock in the Horicon Marsh area in 1947 remained until May 8. On the other hand, the arrival of the first flocks in the James Bay region is quite punctual, generally between April 15 and 25, which is the time of the goosemoon, "nisku pesim," of the Cree Indians. In most years, the earliest flocks arrive on the breeding grounds 2 to 3 weeks before the breakup of the major rivers, table 6.

George MacCloud, a lifelong resident of the James Bay area, reported to the senior author that a second flight of Canada geese generally takes place about June 10. These late geese are said to be in large flocks, whereas most of those that arrive earlier are paired. He thought that the late arrivals were largely young of the previous year. Although we have been in the bay area during June, we are unable to confirm, by personal observation, the "flight of stragglers."

However long the northbound Canada

Table 6.—First arrival or first kill of Canada geese at Fort Albany, Ontario, and date of breakup of the Albany River.*

Year	Arrival of Canada Geese		Date of Breakup of the Albany River	Number of Days Between First Arrival of Geese and River Breakup
	Date	Comment		
1884	May 1	First goose observed	May 17	16
1885	April 26	First goose observed	May 15	19
1888	April 21	First goose observed	May 12	21
1889	April 12	First goose observed	May 6	24
1891	April 15	First geese observed	May 14	29
1896	April 15	First geese observed	May 10	25
1897	April 12	First geese observed	May 7	25
1898	April 14	First geese observed	April 27	13
1900	April 6	First goose observed	May 2	26
1901	April 18	First goose killed	May 1	13
1902	April 14	First goose killed	May 15	31
1903	April 23	First geese observed	May 20	27
1904	April 23	First geese observed	May 8	15
1913	April 17	First geese observed	April 28	11
1914	April 21	First goose killed	May 6	15
1918	April 19	First goose killed	—	—
1919	April 19	First goose killed	—	—
1920	April 25	First geese observed	—	—
Average	...	...	...	*20 6*

* Data on the arrival of Canada geese before 1901 and most data on breakups from Lower (1915); arrival data on Canada geese 1901–1920 from Fort Albany diary of Bishop Robert John Renison and other local sources.

goose flocks may linger in the United States, the final lap over the forested areas of Canada is apparently often made in a single day. Miner (1929) stated that frequently, when flights of geese have left his refuge at a half hour before sundown, he has wired the news ahead to towns lying north between Kingsville and James Bay. The following morning, generally between 6 and 8 o'clock, large flights have been seen over Cochrane, Ontario, a town about 490 miles north of Kingsville. If their course was fairly direct, and if it is assumed that the geese that left the Miner Sanctuary were the ones sighted over Cochrane, a not unwarranted assumption, their average speed was 35 to 40 miles per hour.

A few flocks stop to feed each spring on the farm lands of the clay belt in central Ontario; the New Liskeard area was host to migrating flocks in 1947. In early May of that same year, flocks held up by severe winter conditions remained in the Kapuskasing area sufficiently long to warrant artificial feeding; little natural food was available, as the country was still under several feet of snow, and all rivers and lakes were frozen. Despite this fact, a large flight of Canada geese was reported over Frazerdale the night of May 4, and the following day the first big flight was observed in the Moose River country, nearly 2 weeks before the breakup of the Moose River, which occurred on May 17.

No attempt has been made in the present study to compile additional data on the correlation of Canada goose movements with the advance of the isotherm of 35 degrees F., a correlation reported to hold only for the vanguard of migrants (Lincoln 1939).

WINTER CONCENTRATIONS

The Canada geese of the Mississippi River valley winter from the latitude of southern Wisconsin to the Gulf Coast of Louisiana, using definite concentration areas during the winter season, as well as during the migration periods. They are hardy birds, able to withstand winters of the severity of those occurring in southern Wisconsin and southern Ontario without ill effect, as long as they are provided with abundant food and a water supply. When rest lakes in northern areas become frozen over, the flocks resort to open streams for drinking water, but the lake ice pro-

vides acceptable roosting sites. When the local food supply is exhausted or covered with snow, or when feeding is curtailed, as at the Miner Sanctuary in early December, the geese in the northern sectors of the flyway migrate farther south.

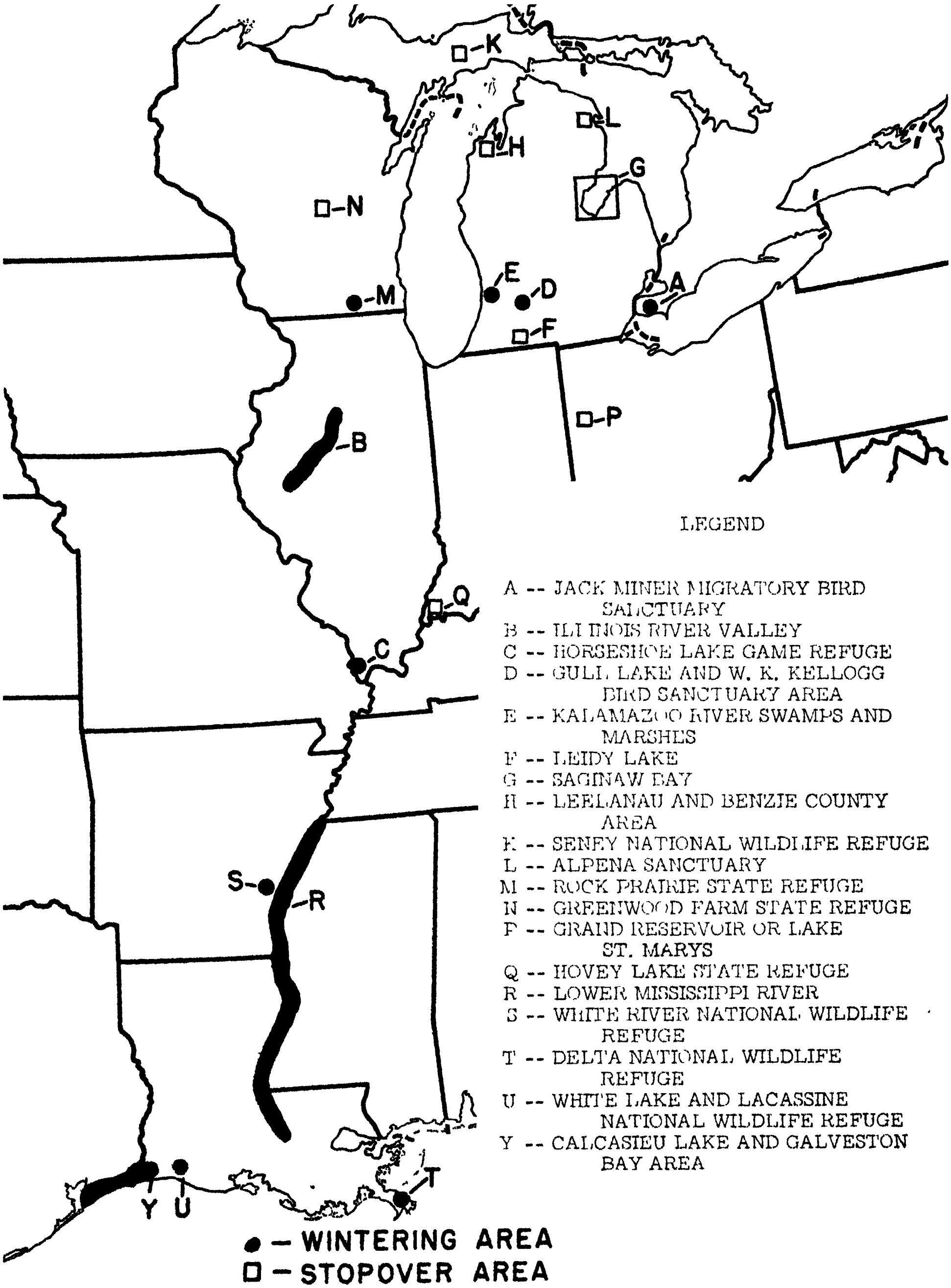

Fig. 39.—Location of important concentration areas for Canada geese of the Mississippi Valley population.

Each January an inventory of the waterfowl populations wintering in the United States is made by the United States Fish and Wildlife Service and cooperating agencies, assisted by selected private individuals. The January inventories have produced useful information, particularly in regard to population trends but, because these inventories are taken over a limited period of time (4 days), in some areas they have been subject to considerable error in past years. For example, the immense coastal marshes of Louisiana, which are notoriously difficult to traverse on the ground, cannot be covered adequately except by plane. Because thorough aerial censuses of the Canada goose population in Louisiana were not made before the winter of 1943–44, and because adequate data are lacking for many other parts of the flyway prior to that winter, we do not consider the population data previous to that date to be of sufficient reliability to meet present-day management needs. Even some of the data in table 7, particularly the 1944–45 figures for the populations in Arkansas and on a considerable portion of the lower Mississippi River, may not be of sufficient reliability because complete coverage by aircraft was not possible.

For reasons explained in the section "Autumn Migration Routes," we believe that the flocks of western Louisiana probably are not an integral part of the Mississippi Valley population. Nevertheless, they should be considered along with the Mississippi Valley population in order to detect whether major population shifts occur between the flyways in some years and to determine the effect that kills in the upper Mississippi River valley may have on the western Louisiana populations. A brief survey of the various concentration areas and the populations using them follows.

Jack Miner Bird Sanctuary

The Jack Miner Bird Sanctuary, located in the rich farm lands of Essex County, Ontario, figs. 39*A* and 40, 4 miles from Lake Erie, was one of the first waterfowl refuges established in North America. The history of this refuge and of Jack Miner's work with Canada geese has a bearing on discussions

Table 7.—Population of Canada geese in the Mississippi River valley, 1943–44 through 1946–47. Data are from the annual January inventories, except as noted.

State or Other Area	Season			
	1943–44	1944–45	1945–46	1946–47
Michigan	4,220	2,200	2,343	3,512
Wisconsin	6,350	4,100	4,310	5,000
Minnesota	—	5	100	—
Ohio	248	—	—	105
Indiana	343	750	985	1,369
Illinois (Mason County)	925[1]	800[1]	360[1]	31,649[2] (Illinois and Horseshoe Lake combined)
Horseshoe Lake	37,000[3]	30,000[4]	22,000[3]	
Iowa	125	6	—	—
Kentucky	3,720	2,280	1,200	1,230
Mississippi River (Tenn.-Miss. line to White Castle, La.)	3,300[5]	10,000[6]	1,650	7,540
Arkansas	5,000[5]	10,500	5,400	800
Missouri	3,300	5,440	665	2,370
Louisiana Delta	1,000[5]	1,000[5]	10,000[7] (Louisiana Delta and Western Louisiana combined)	8,065[7] (Louisiana Delta and Western Louisiana combined)
Western Louisiana	11,000[5]	12,000[5]		
Total	*76,731*	*79,181*	*49,013*	*61,640*
Total, exclusive of western Louisiana	65,731	67,181	—	—

[1] Census by Frank C. Bellrose, Illinois Natural History Survey.
[2] Of the number of Canada geese in Illinois, about 30,000 were at Horseshoe Lake and 800 at the Union County refuge.
[3] Census by Paul S. Smith, United States Fish and Wildlife Service, and Harold C. Hanson at January inventory.
[4] Average of estimates by Robert H. Smith, Paul S. Smith, and Frank C. Bellrose after hunting season.
[5] Census by Robert H. Smith.
[6] Total for Tennessee and Mississippi combined in January inventory.
[7] Inventory figure for all of Louisiana. According to Richard H. Griffith, United States Fish and Wildlife Service, 1,500 Canada geese were at the Delta National Refuge and 5,440 at the Lacassine and Sabine National Wildlife refuges in the winter of 1946–47.

in this paper and is also of general interest.

Jack Miner (1923) built his first pond and set out decoys to attract geese in 1904, but did not lure in a family of geese until 1908. The numbers of geese using the refuge built up slowly in the early years, and until 1915 the refuge attracted Canada geese only in the spring. In later years the autumn flight equaled the spring flight in size.

Efforts at trapping and banding Canada geese did not succeed until 1915, and large-scale bandings were not accomplished until nearly 10 years later. Table 2 presents the best available data on the numbers of Canada geese banded at the Jack Miner Bird Sanctuary in the autumn.

The Miner homestead, ponds, and feeding grounds consist of 17 acres. All feeding is done around the ponds, but a few rye and timothy fields are planted as retreats and sources of food to be used when the geese on the ponds are disturbed. Additional farm land, owned by the Jack Miner Migratory Bird Foundation, Inc., amounting to 400 acres, surrounds the 17-acre homestead area. About 100 acres are planted to rye and timothy, the remainder to corn, which constitutes the only grain fed to the geese. Fields of timothy, which have been cut for seed, are said to make ideal pastures for Canada geese and are heavily grazed. Approximately 20,000 bushels of ear corn are fed during the autumn and spring seasons; when there is an appreciable local kill the corn is fed more heavily than at other times.

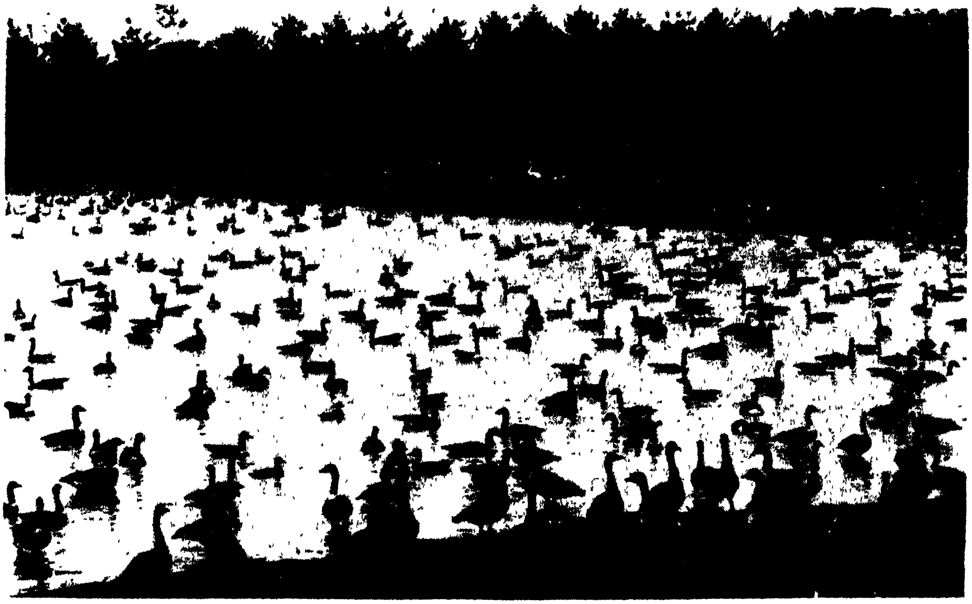

Fig. 40.—View of the main pond and feeding grounds at the Jack Miner Bird Sanctuary, Kingsville, Ontario. Contact of the geese with human beings is avoided whenever possible. Corn is distributed at night, and visitors remain concealed while observing the geese.

By Proclamation and Order in Council of the Provincial Government, no shooting is permitted on an additional 1,600 acres of land neighboring the 400 acres owned by the Miners. Thus, the geese are protected in all directions from the central feeding grounds by a buffer strip about 1 mile deep.

A few geese arrive at the refuge by late September. Noticeable increases in numbers usually occur between October 10 and 15, and peak numbers are reached by about November 10. There is a constant renewal of the population as some individuals continue their migration south and others arrive from the north. The bulk

of the autumn flock leaves by late November or early December. In some years prior to World War II, as many as 5,000 geese were reported to have remained all winter. Some of these wintering geese from the autumn flight have received "S" marked bands in the spring along with birds that have wintered at Currituck Sound and Lake Mattamuskeet, thereby explaining why some spring bands are subsequently recovered in the Mississippi River valley, fig 12.

Illinois

Of the areas in Illinois important to migrating and wintering flocks of Canada geese, the twc most important are the Illinois River valley and the Horseshoe Lake Game Refuge in Alexander County at the southern end of the state.

Illinois River Valley.—Canada geese have been reported from 23 bottomland lakes in the Illinois River valley, fig. 39*B*, but regularly from only seven lakes, table 8. These lakes act chiefly as roost areas; feeding is done in the cultivated uplands and in some drainage districts. Geese of five of the Illinois concentrations disperse to feed as follows: Beebe Lake geese depend largely on the winter wheat and the corn of Duck Island; Lake Chautauqua and Clear Lake geese feed mainly in the cultivated fields of Mason County; Crane Lake and Jack Lake birds seek most of their food in or near a 1,000-acre private club 2 miles southeast of Bath. Flocks frequenting Goose Pond and Lake Senachwine (the part formerly known as Swan Lake) have not been observed feeding in any particular sector. In general, feeding areas are within 7 miles of a roost lake. Population data for the above areas are summarized in table 8.

Horseshoe Lake Game Refuge.—The most important Canada goose wintering ground in the Mississippi River valley in recent years, the Horseshoe Lake Game Refuge, with its surrounding area, figs. 1 and 39*C*, during the period of this study harbored approximately 50 per cent of the goose population of the flyway for varying autumn and winter periods. Because of inadequate food supplies on the refuge, as well as intense hunting pressure in surrounding privately owned fields, the flock fed in most winters over a 15-mile radius. The majority of the geese roosted within the refuge each night, although some flocks resorted to islands and bars in the Mississippi River.

The lake, fig. 41, 1,200 acres in size, of an oxbow type common to the bottomlands in the flood plain of the Mississippi River, in many places is 200 or more yards in width and 4 to 6 feet in depth. A dam maintains fairly stable water levels, but most of the land enclosed by the lake is subject to flooding when the Mississippi or Ohio River reaches high flood stage. Open water surrounds the island except for a

Table 8.—Canada goose populations in three regions of the Illinois River valley, autumns of 1938–1946.

Year	Bath Region (Jack, Crane Lakes)		Chautauqua Region (Chautauqua, Clear, Beebe Lakes)		Putnam Region (Goose Pond, Lake Senachwine*)		Approximate Average Number in Valley
	Peak	Average	Peak	Average	Peak	Average	
1938...	1,420	800	75	22	?	60	882
1939.	2,100	520	500	34	?	100	654
1940...	800	509	250	110	?	83	702
1941.	1,500	391	337	84	37	?	475
1942..	1,340	1,150	325	400	80	60	1,610
1943...	1,900	500	300	425	400	?	925
1944...	1,600	400	150	400	14	?	800
1945.....	1,400	0	330	360	46	?	360
1946.....	500	285	430	281	190	86	652
Total...	*12,560*	*4,555*	*2,697*	*2,116*	*767?*	*389?*	*7,050*
Average.	1,398	506	300	235	—	—	784

*Part of Lake Senachwine formerly known as Swan Lake.

Fig. 41.—View of the east arm of Horseshoe Lake. The large open expanses of the lake are favored by the geese for roosting purposes.

Fig. 42.—The greater portion of Horseshoe Lake is open water, but the north and south portions have heavy stands of live and dead cypress and tupelo gum trees. A dam maintains fairly stable water levels except when the Mississippi or the Ohio River reaches high flood stage.

Fig. 43.—Aerial view of Canada geese on Horseshoe Lake in November, 1945. The population of the entire flock could be counted with a considerable degree of accuracy if suitable aerial photographs were available.

small portion at the north end, where the lake is swamplike and has an irregular stand of tupelo gum and cypress trees, fig. 42. Gums and cypresses border the remainder of the lake, and in some places the cypresses extend entirely across the lake.

During late years of this study the refuge contained about 3,660 acres. The

Table 9.—Number of Canada geese using the Horseshoe Lake Game Refuge, 1928–29 through 1946–47.

Season[1]	Peak Number	Number at January Inventory	Total Loss (Including Crippling Loss, from Table 15)	Approximate Number of Geese to Arrive at Refuge During Fall and Winter
1928–29	1,000–1,900[2]	—	—	—
1929–30	7,000–8,000[2]	—	—	—
1932–33	30,000[2]	—	—	—
1940–41	45,000	17,000	—	—
1942–43	55,000	15,000	—	—
1943–44	50,000	37,000	15,980	53,000
1944–45	35,000	30,000	10,549	40,500
1945–46	26,000	22,000	7,117	29,100
1946–47	—	31,641	—	—

[1] The term *season* refers to the period of time in autumn and winter that the geese are at the refuge.
[2] From Uhler (1933). Other censuses except last two by Illinois Natural History Survey staff and Paul S. Smith; 1945–46 and 1946–47 census by Survey staff and Robert H. Smith.

island has an area of 1,360 acres, of which 1,200 have been farmed in recent years to produce food for the geese. The remaining acreage supports some of the finest virgin bottomland timber in the state. Of the cultivated portion of the island usually 300 to 400 acres are planted to corn and 700 acres sown to wheat, but these acreages have varied considerably from year to year. In the last several years all crop land on the island has been planted in corn. Wheat or corn is sown on the 100 acres of the refuge adjoining the east shore across from the island.

Many of the published statements in recent years regarding the size of the Canada goose flock at Horseshoe Lake have not been in agreement. The result has been confusion in the minds of the public. While a few "census figures" have been based on pure guesswork and are therefore unreliable, many of the differences in published data may be related to the times of the year the censuses were taken, and whether they included only the number of birds alive on certain dates or the total number arriving at the refuge in any given year. The population data given in table 9 summarize the census figures for several years.

Population estimates of the Horseshoe Lake flock since 1939 have been made by staff members of the United States Fish and Wildlife Service and the Illinois Natural History Survey, table 9. These estimates have been made by visually dividing the flocks into blocks, counting the number of geese in the sample blocks when the great bulk of the geese are feeding in the wheat fields on and near the refuge, and then using the sample counts to calculate the total population. The practice in some years has been to make periodic estimates from the time the first geese arrived in late September until peak populations have been reached in late autumn. Since 1944, aerial censuses just before and after the hunting seasons have

Fig. 44.—Aerial view of Burnham Island and adjacent bars in the Mississippi River, 4 miles west of Horseshoe Lake. Prior to the establishment of the refuge, Canada geese wintered in large numbers on similar bars and islands of the Mississippi River, from Chester to Cairo, Illinois. Geese have made some use of these islands even since the refuge was established.

been made at Horseshoe Lake and nearby areas, figs. 43 and 44. Population figures for 1941–42 through 1945–46 are shown graphically in fig. 38.

Michigan

In Michigan there are three major concentration areas and two of minor importance.

Kalamazoo River Bottoms and Nearby Lakes.—The Kalamazoo River bottoms and a number of lakes in the southwestern section of the state constitute the most important region in Michigan for concentrations of migrant and wintering Canada geese, fig 39. This general area includes three specific concentration sites.

1. Gull Lake and the W. K. Kellogg Bird Sanctuary and Farms are located in Prairieville and Barry townships in Barry County and in Richland and Ross townships in Kalamazoo County, fig. 39*D*. Gull Lake, with an area of 3,000 acres, is designated as a rest lake. Hunting is prohibited on the quarter-mile strip surrounding this lake and on the Kellogg tract of 600 acres.

The above district lies on an extensive outwash plain and is characterized by small lakes and kettle holes. Some nearby sections are too hilly to be farmed, but hay, corn, and wheat are raised extensively on the less hilly sections. The geese feed in the cultivated upland fields and also they are hunted there.

In 1945, the maximum autumn population in the area was 5,000 birds, and about the same number were present during the peak of the 1946 spring migration. The wintering population usually varies from 1,000 to 2,000, but may be considerably less for several weeks in midwinter. In 1944–45, 500 geese wintered at Gull Lake (Dr. Miles D. Pirnie, then in charge of the sanctuary, personal communication). Normally a majority of the birds leave by mid-January and return again by mid-February. Weather determines their movements; usually a portion of Gull Lake remains open throughout the winter, and waste grain is generally available in the uplands for geese that winter in the area.

2. The Kalamazoo River swamps and marshes, fig. 39*E*, principally the Pottawattomie and Ottawa marsh areas, the latter a part of the Swan Creek Wildlife Experiment Station located in Heath, Manlius, and Valley townships, and the Todd Farm Sanctuary in Ganges and Clyde townships near the Kalamazoo River, all in Allegan County, are some of the most important concentration grounds for Canada geese in Michigan. Each site differs somewhat from the others and there is a free interchange of birds from one area to the other.

The Pottawattomie and Ottawa areas consist of 2,800 acres, principally marshy bottomlands with adjacent timbered areas. These areas serve as both private and public hunting grounds.

The Swan Creek Wildlife Experiment Station has a 550-acre sanctuary of partially flooded land, once farm land, and timbered bottomland.

The Todd Farm Sanctuary comprises 1,500 acres of drained lake-bottom farm land. This sanctuary furnishes both feeding and resting sites. Hutchins Lake, north of the farms, is used by geese as a rest lake in the autumn. A spring-fed creek crossing the farm remains open through the winter, and food is available to the geese in the cultivated fields.

The greatest concentration of geese recorded in the above sections was 6,000, in the autumn of 1945. The wintering flock was estimated at 2,000. Both figures are said to represent spectacular increases in comparison with those of previous years. In 1944 the wintering flock was estimated to be only 400.

3. A 250-acre sanctuary at Leidy Lake in Leonidas Township, St. Joseph County, fig. 39*F*, serves as an important spring concentration point; over 2,000 geese were estimated to be on the area in 1946. It is used less in the autumn, 300 to 400 being average numbers of geese present at that time.

Saginaw Bay.—Saginaw Bay is a major concentration area for both autumn and spring flights of Canada geese, fig. 39*G*. The spring flights may consist largely of South Atlantic geese en route north from the Miner Sanctuary. The geese do not linger long at Saginaw Bay in the autumn because of the absence there of sanctuaries. They have been forced by hunting pressure to reverse their normal

daily routine, feeding after dusk in the grain fields and roosting in daylight hours on the open waters of the bay. They do not winter in this sector, as there is no open water.

The best estimates available place the maximum numbers frequenting the bay during the autumn or spring migrations at about 15,000 birds.

Leelanau and Benzie Counties.—Leelanau and Benzie counties in Michigan fig. 39*H*, constitute a less important concentration area than the Kalamazoo River or Saginaw Bay areas. A number of scattered sites are favored: Glen Lake and about four sections of hilly grassland in Empire Township, Leelanau County, and Lake Ann, Upper Platte River, and Platte Lake in Benzie County. A 1,200-acre refuge recently established in Empire Township provides feeding and resting areas.

Canada geese have used this area as a regular stopping place for only about 10 years. In recent years as many as 2,000 geese have frequented it regularly, but few winter in the area; there were about 50 in 1945. Some Canada geese may nest in this region.

Other Michigan Areas.—There are two other concentration areas in Michigan of less importance than the above. The Seney National Migratory Waterfowl Refuge, fig. 39*K*, consists of 30,000 acres surrounded by a vast area of wild land. The autumn concentration in 1945 was estimated at 3,000 geese. The spring maximum was 2 500.

The Alpena Sanctuary, fig. 39*L*, comprises 500 acres of land on the Thunder Bay River in Alpena Township, Alpena County. Geese stocked at this refuge have attracted as many as 400 migrants in the autumn.

Wisconsin

In Wisconsin there are two refuges or concentration areas of importance.

Rock Prairie Refuge.—The Rock Prairie Refuge, fig. 39*M*, consisted of 640 acres when established in 1936. Before the refuge was relocated, it lay partly in Richmond Township, Walworth County, and partly in Johnstown Township, Rock County. In 1945 the refuge was shifted 3½ miles to the west so that it lay entirely within Rock County.

The entire refuge is in cultivated prairie uplands and is used for feeding only. Since feeding was initiated in 1940, between 25 and 45 tons of corn have been fed each season. The geese that frequent this refuge in the autumn and winter usually fly to Lake Geneva and Lake Koshkinong for roosting.

Canada geese do not remain in southern Wisconsin during severe winters. In 1945–46, local estimates placed the wintering flock at 3,000. In 1942, 4,500 geese wintered in these two counties (Zimmerman 1942). Peak autumn populations in Rock and Walworth counties have generally varied from 4,000 to 6,000 birds. The build-up in numbers of geese in the autumn of 1942 is shown graphically in fig. 38.

Greenwood Farm Refuge.—The Greenwood Farm Refuge, established in 1940, contains 1,751 acres. It is situated in Hancock and Deerfield townships, western Waushara County, fig. 39*N*. Although it is intended primarily as a rest area, in some parts of this refuge farmers are paid to leave corn standing in the fields for the geese. The flocks roost on the sand bars of the Wisconsin River, about 20 miles to the west. The refuge was first used by a few geese in 1942; as many as 3,000 birds had been reported on the area by 1946.

Ohio

Lake St. Marys, or Grand Reservoir, fig. 39*P*, a 17,500-acre impoundment in Mercer and Auglaize counties, is heavily used by Canada geese in migration, but few geese winter there or in other parts of Ohio. January inventory figures, 1941–1946, show an average of only 400 Canada geese in the entire state; inventory figures for the state, 1936–1941, averaged 1,600 per year.

Indiana

Hovey Lake, fig. 39*Q*, the most important wintering area for Canada geese in Indiana, is located in Posey County in the extreme southwestern tip of the state, 4 miles from the confluence of the Wabash and Ohio rivers. The lake and adjoining marsh and swamp land, totaling 900 acres, were purchased in 1938 with funds made available through the Federal Aid

in Wildlife Restoration Act. The lake, nearly a half mile wide and three-quarters of a mile long, has an area of about 400 acres. Bald cypress is found around certain parts of the lake, but willow, elm, and soft maple, with an understory of buttonbush, occupy most of the shore line.

Approximately half of the lake is open to waterfowl hunting; the remainder is a refuge. No supplemental feeding is carried out on the refuge sector, a factor that may partially explain why the geese that use the area have retained their wildness. Nearby wheat fields are cropped by the geese to a considerable extent, but no serious damage has been reported. During the winter period the geese do much of their feeding in overflow, bottomland cornfields that have been harvested with mechanical pickers.

There are seldom more than 300 geese in the vicinity of Hovey Lake during the hunting season. Maximum numbers during three recent winters are as follows: 1,000 on January 8, 1944; 1,500 on January 20, 1945; and 2,000 on January 27, 1946.

Arkansas

The geese wintering in the lower White River and Arkansas prairie area, fig. 39S, use several distinct types of habitat: the flood-plain swamp lakes of the White River National Wildlife Refuge, the neighboring prairie area of Arkansas County, and the sand bars of the lower Arkansas River and adjacent parts of the Mississippi River.

The flood-plain lakes are shallow, cypress-rimmed oxbows, devoid of submerged vegetation and used by the geese only for roosting. The geese make daily flights from these lakes to the prairie for feeding. The prairie is intensively cultivated; rice, winter oats, soybeans, and lespedeza are the principal crops. The practice of leaving the rice fields fallow periodically and using them for pasture makes attractive foraging areas for geese, as the ground between the old rice levees is frequently flooded or at least wet during the winter.

Because of the difficulty of censusing the extensive areas of bottomland swamps, we believe that in most years our data on populations in Arkansas are not reliable. In the winter of 1943–44, the population was successfully censused and estimated to be 5,000, but we are unable to state with any certainty what the population was in prior or subsequent years, as the birds wintering in this region occasionally use the Mississippi River bars and may have been included in the estimate for the Mississippi River area. Duplications in the inventory figures for Arkansas and the lower Mississippi River in 1944–45 may account for the indicated increases for this region in that winter and partially explain the apparent sudden great drop in the total population of Mississippi flyway geese in the following year, table 7.

Lower Mississippi River

Islands and bars in the Mississippi River attractive to wintering Canada

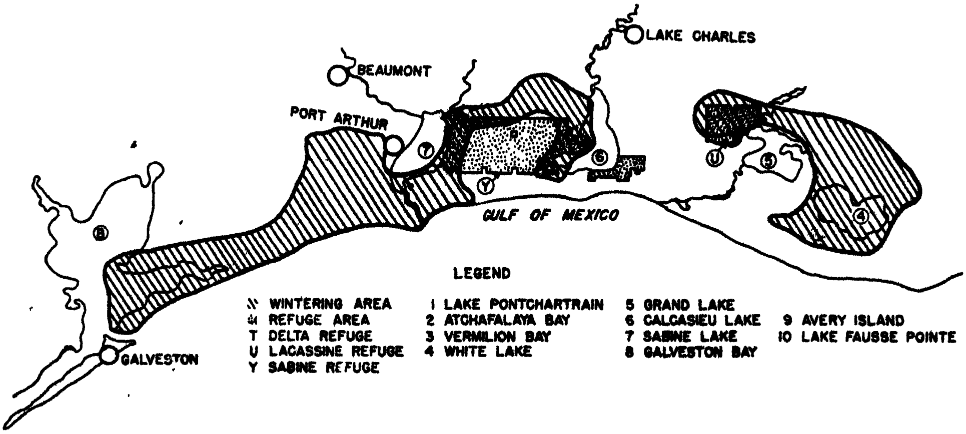

Fig. 45.—Location of wintering grounds of Canada geese on the coast of the Gulf of Mexico.

geese extend north to Chester, Illinois, and south to White Castle, Louisiana. However, except for scattered flocks, few Canada geese have wintered on the Mississippi River between Cairo, Illinois, and the Tennessee-Mississippi state line in recent years.

The portion of the Mississippi River used by Canada geese throughout the winter, fig. 39*R*, has an area, from levee to levee, of well over 1,500 square miles. In this huge expanse of territory the channel has constantly shifted by cutting and tearing on one side and depositing on the other; the result is a labyrinth of chutes and oxbows that have formed numerous islands and bars. Each island usually has one or more sand bars, and most of the bends in the channel have bars on the inside, fig. 44. Portions of the higher islands and bars, covered with small switch willows, grasses, and sedges, are used as feeding areas by the geese. At times, the bark of the small switch willow appears to be staple food of geese throughout the area.

The geese using this section of the river are widely scattered; usually they are in small or medium-sized flocks, but occasionally in large flocks. They show a preference for certain bars, which they use year after year. Varying water stages affect the accessibility of the bars to the geese and may cause the flocks to shift about when water levels change rapidly.

In primitive times the geese depended on forage produced on sand bars and in shallow flood-plain lakes, since there were then no cultivated crops in the bottomland country. Early agricultural developments tended to keep them on the bars in the southern sections of the flood-plain and upper delta country because cotton and sugar cane were the only crops extensively raised. Each year increasingly large acreages are planted to winter grains and legumes in the north and central portions of the bottomlands, thereby increasing the food resources for the geese in that section.

The habitat at Grand Lake and Lake Fausse Pointe, fig. 45, while near the coast, is of the sand-bar type rather than marsh. The geese are found on the upper ends of the lakes where the distributaries of the Atchafalaya River have formed a subdelta, creating conditions very similar to those found on the river sand bars. The geese sometimes work back and forth across the Atchafalaya swamp between Grand Lake and the Mississippi River, as less than 25 miles separate the lake from White Castle, Louisiana, the nearest point on the river.

Our data on goose populations in this sector of the valley are meager. Estimates made by the United States Fish and Wildlife Service have varied from 1,600 to 10,000 geese between 1944 and 1946. Accurate census figures are especially

needed from the lower Mississippi River each year, because data from this area are apt to indicate to what extent kills made in the Horseshoe Lake region are at the expense of populations wintering below Cairo, Illinois.

Coastal Marshes

The coastal marshes of Louisiana and east Texas extend from the mouth of the Mississippi River west to Galveston Bay. In this vast expanse of marsh, totaling over 5,000,000 acres, less than 700,000 acres are inhabited by Canada geese. Western sections of this range are used also by white-fronted geese, and between the Delta and Rockefeller refuges the winter range of the Canada goose is overlapped by that of the blue and snow geese.

In the coastal marshes are three principal concentration areas for Canada geese, figs. 39 and 45, and, as these vary somewhat as to type of habitat involved, each is discussed separately.

Delta of the Mississippi River.—At the mouth of the Mississippi River, Canada geese are concentrated on the Delta National Wildlife Refuge and the adjacent area in the vicinity of Main Pass, *T* in figs. 39 and 45. Here they use a variety of marsh types, from the relatively hard deltaic flats bordering the Gulf Coast to the deep marsh—the "floating prairie" of the interior. This is the most isolated wintering area on the Louisiana section of the Gulf Coast. The marshes to the west between the Delta Refuge and White Lake, an air-line distance of 180 miles, are devoid of Canada geese, except for a small flock inhabiting Avery Island.

White Lake and Lacassine Refuge.—In the White Lake and Lacassine area, Canada geese occupy an extensive range (*U* in figs. 39 and 45): east to Cow Island, north to the edge of the prairie below Guéydan, west to Sweet Lake, and south to the Rockefeller Refuge, which lies below Pecan Island; the range does not include Grand Lake and Lake Misere. Within this area Canada geese are most abundant south of Gueydan, where prairie and marsh merge, and on the Lacassine Refuge. In the zone of contact between the prairie and the marsh, there are marginal rice fields and wet pastures, interspersed with patches of maidencane, *Panicum hemitomon,* and southern wildrice, *Zizaniopis miliacea.* A vast expanse of maidencane and Jamaica saw grass, *Mariscus jaimaicensis,* with occasional low grassy ridges, is found throughout the marsh between White Lake and the edge of the prairie. At the west end of Pecan Island there are old stranded beach ridges roughly paralleling the coast line. The ridges, pastures, and rice fields are used extensively by geese for feeding areas. The deep marsh is used primarily for roosting.

Calcasieu Lake to Galveston Bay.—The Canada geese occupying the range from Calcasieu Lake to Galveston Bay are found on Calcasieu and Sabine lake ridges, the edge of the prairie, and the relatively high sea-rim marshes from Johnson Bayou to Port Bolivar, Texas, (*Y* in figs. 39 and 45). The Louisiana section of this range is limited, consisting only of a narrow fringe around an extensive area of deep marsh. In Texas, however, the reverse is true: a wide area of sea-rim and prairie marshes around a relatively small area of deep marsh. Consequently, almost the entire Texas area is good Canada goose range. The marshes in this area, along with the high marshes of southwestern Louisiana, are heavily grazed by cattle, which keep the forage in an ideal condition for feeding geese. The geese frequently roost on the inshore waters of Calcasieu and Sabine lakes and Galveston Bay, as well as on such smaller water areas as Black and Brown lakes.

Inventory of goose habitat on the Gulf Coast in 1943–44 and 1944–45 revealed populations of 12,000 and 13,000 birds, respectively. Partial coverage of the Gulf Coast in 1945–46 indicated no significant change in numbers over the previous 2 years. The above figures represent great divergence from what was commonly believed to be the Canada goose population on the Gulf range. Vast areas of excellent marsh are unused by Canada geese. Alfred M. Bailey stated (personal communication) that, even in the late twenties, Canada geese could be found in only a few places on the Gulf Coast. The geese frequent these same places today.

"It has become scarcer of late years," Bailey & Wright (1931) wrote several

years ago regarding the Canada goose population on the Gulf Coast. While there may have been much greater numbers of Canada geese wintering in the marshes of Louisiana 25 or more years ago, the decrease to present-day populations has not occurred altogether in recent years. It is more likely that the decrease was a gradual one, probably much of it caused by heavy shooting in northern parts of the range and in Louisiana. It seems altogether probable that at least some of the geese that normally would have wintered in Louisiana have been decoyed into Horseshoe Lake for entire seasons and have contributed to the annual kills there, but data are not available to show the extent to which hunting at Horseshoe Lake has affected Gulf Coast populations. For reasons discussed under "Autumn Migration Routes," it is difficult to believe that the kill made at Horseshoe Lake in any recent year would materially affect Louisiana populations the same year, for there are no data to show that an appreciable turnover in the population occurs at Horseshoe Lake within a single season.

In 1943–44, aerial coverage showed the following distribution of the Gulf Coast Canada goose populations: Delta Refuge 1 000, White Lake and Lacassine Refuge 7,000, Sabine Refuge (Gum Cove and Hackberry Island) 4,000.

GOOSE BEHAVIOR AND HUNTING LOSSES

The tremendous number of Canada geese bagged in the vicinity of Horseshoe Lake in recent years has made this area one of the most widely publicized shooting spots on the continent. The fearless and unwary behavior of the geese that winter at the Horseshoe Lake Game Refuge is responsible in large measure for the heavy kill, fig. 46. The response of this flock to hunting is contrary to the traditional reputed behavior of Canada geese. For centuries, the Canada goose has been extolled as one of the wisest and wariest of all birds and has been regarded as one of the most difficult to hunt successfully, but hunters and personnel engaged in wildlife management who have observed the habits of the Horseshoe Lake flock in Alexander County agree that these habits do not conform to the traditional pattern of Canada goose behavior.

How can the behavior of the Canada goose in Alexander County be reconciled with its traditional reputation? If the species is so wary or intelligent, why is it so unsuspicious and easily killed in Alexan-

Fig. 46.—A portion of the Horseshoe Lake Canada goose flock near the refuge headquarters. In many years, when food was scarce this flock lost much of its normal wariness.

der County? That the traits of the Horseshoe Lake flock are apparently singular cannot be denied, but there are many clues in the literature that help to explain its seemingly perplexing behavior. For example, many authors, after discussing the sagacity of the Canada goose, cite examples of the behavior of this goose that conflict with their previous remarks.

Grinnell (1901) has aptly expressed the enigmatic behavior of Canada geese: "The wild goose has long been proverbial for his shyness and wariness, and he well deserves the reputation that he has gained, and yet sometimes he is found to be 'as silly as a goose.' So that the gunner who follows the geese enough to see much of them will find that at one time great acuteness and at another a singular lack of suspicion are present in the ordinary wild goose. Few birds are more difficult to approach than these, and yet few come more readily to decoys or are more easily lured from their course by an imitation of their cry." A veteran goose hunter describes the Canada goose as "a bird of many moods. At times, very wise, but at other times very foolish" (Darby 1916).

Barnston (1862), referring to the Canada goose in the Hudson Bay region, writes: "Its disposition has less of wildness in it than that of the snow goose."

These citations and others given below show that many of the traits which make Canada geese vulnerable to hunting have been recognized elsewhere in the country, indicating that the behavior of the Horseshoe Lake flock is not as unique as one might be led to suspect. The unusual aspect of the reactions of the Horseshoe Lake geese seems to be that all or most of their behavior traits that tend to make them vulnerable to hunting are exhibited in the vicinity of Horseshoe Lake.

Wariness, Innate and Acquired

Many observers point out that geese are not so wary as various species of ducks, especially the mallard and black duck. Brandt (1943) noted a difference in wariness even in the newly hatched: "Young ducks of most kinds, just hatched, are very wild little creatures, which scatter at once and hide by all sorts of ruses. Newly hatched geese are most trusting little fellows."

The origins of the behavior differences between ducks and geese are deeply rooted. Lorenz (1937), Lack (1941), and Tinbergen (1942, 1948) have contributed to an understanding of these origins, which seem to relate in an important degree to the "innate perceptory patterns." There appears to be an inverse relationship between the specificity and specialization of these patterns and the degree to which the behavior patterns are (1) directed by "imprinting" (Lorenz 1937) during a brief period after hatching and are (2) developed, subsequent to the imprinting stage, by associative learning.

The acute wariness that adult geese normally possess seems to be mostly an acquired trait. Experience and association of the young geese with older birds appear to play an important role in the development of the traditional behavior pattern. If newly hatched goslings are taken before they have left the nest and are hand reared, their subsequent behavior shows considerable divergence from that of the wild birds. The readiness with which the Canada goose will become semidomesticated when given protection may possibly be related to the slow development of wariness in young birds.

A factor contributing to the fearless behavior of the Horseshoe Lake geese is the dual role played by man on and in the vicinity of the refuge. As the geese are accustomed to the sight of refuge workers, visitors, and the activities of a relatively dense rural population outside the refuge from the time they arrive in the autumn until the opening of the hunting season, they are apparently unable to comprehend the unfriendly role of the hunter. The same reaction to man has been found to be true in other places. Todd (1940) writes, "Under the protection now afforded at Erie Bay, the geese are less wary; on March 25, 1932, a party of which I was a member saw about twenty-five resting on the shore of a sheltered cove, and without apparent concern they permitted us to drive up in an automobile within one hundred feet."

Stone (1937) relates how Canada geese have responded to food and protection on the Atlantic Coast: "In season the farmers of this region [Cecilton, Maryland] go goose shooting on the

wheatfields and have decoy Canada geese to attract the wild birds. Of late years the ground has been baited and the geese return year after year to the places where they have been fed, which accounts for their abundance and tameness." (Notes from a field trip taken in February, 1927, when decoys and baiting were permitted.)

Even when Canada geese are wintering along the vast coastal marshes of the Gulf of Mexico, where, with an abundance of natural food, they might be expected to retain their independence, free-flying wild individuals will momentarily accept man at close range. At the Florence Club, near Gueydan, Louisiana, geese formerly used for decoys and tame cripples are brought into the club grounds for feeding each evening by calling and beating on a tin pan. On these occasions, numbers of wild geese accompany the tame birds into the club grounds and feed from the caretaker's hands. At all other times these same individuals seem to be unapproachable.

The importance of the role of man in conditioning the behavior of an entire flock was brought forcibly to our attention at the Miner Sanctuary. Until about 1925, wild Canada geese using the sanctuary were fed at a pond, 150 feet in diameter, which is located a few yards from the secondary road that passes in front of the Miner home. During the migration periods, when the geese were fed at this small pond, they were usually under the observation of large numbers of visitors, who, unconcealed, viewed them at close range. As a result of this encouraged familiarity, the vigilance of the geese toward man relaxed to such an extent that the local kills increased. Because the situation needed to be remedied, the geese were fed at a larger pond, fig. 40, away from the road, where they were hidden from public view by a dense grove of pine trees and a tight, 7-foot, wooden fence. Visitors who wanted to view the main concentration were required to use blinds or an observation tower overlooking the ponds. The resultant change in the behavior of the geese was profound, and local kills were soon reduced. After these new management measures were instituted, the sight of man was usually sufficient to flush the geese; previously, they had to be practically driven out of the front pond before they would take flight.

Although the Canada goose possesses mental powers that at times seem to be superior to those of most birds, and that are undoubtedly of great survival value under primitive conditions, individuals appear unable to solve problems of self-preservation that arise in a highly modified environment such as that in the Horseshoe Lake region. During the hunting season the geese wintering in that region exhibit almost a complete disregard for gunfire, flying back day after day to fields that often are the most heavily shot. This situation has perhaps been aggravated in recent years by the fact that the geese can feed in these same fields with impunity after the close of the day's shooting but are shot at on returning to feed the next day. The flock as a whole appears to be baffled by the presence of food and protection on the refuge at all times, and by the presence of food (standing corn, winter wheat) at all times but protection only a part of the time away from the refuge.

Family Grouping

Jenkins (1944), in a report on the social organization of a family of geese, states that "This well-integrated [Canada goose] family might be called a family supra-organism, since it performs the activities of a larger, more complex individual, through coördination of its components. This results in the dominance of the family, which is of survival value to its members in that they can feed first and rest in the center of the aggregation and are not pecked or chased."

Strong family ties in geese are undoubtedly of survival value against natural enemies, each family being a protective unit. Against man, during the hunting season, family grouping proves to be a liability, as the death or injury of one member frequently lures the rest of the family within gun range. Many a veteran goose hunter can cite examples of surviving members of a family flock, confused by the loss of one of its members, returning to a shooting pit to be shot at again. Bent (1925), in describing the duck-stand method of shooting geese on the inland ponds and lakes of Massa-

chusetts, writes, "When the geese are near enough and properly bunched a raking volley from a battery of guns is poured into them and other shots are fired as the survivors rise, with the result that very few are left to fly away. Even some of these may return and be shot at again if the leaders or parents of the young birds have been killed." This behavior trait has also been reported by Phillips (1916): "Now if a successful shot [probably meaning a series of shots fired at one time] is finally made into such a flock, and perhaps one half or three fourths of their number have been killed, the remainder, after a few turns in the air, or a short flight of five or ten minutes, will almost always return to the pond, where, if not actually disturbed, they will remain from several hours to a day or so. Sometimes they will decoy a second time."

The closely allied little cackling goose, *Branta minima,* sometimes exhibits the same type of behavior. "Even upon first arrival [in Alaska] many of the birds appear to be mated, as I have frequently shot one from a flock and seen a single bird leave its companions at once and come circling about, uttering loud call-notes. If the fallen bird is only wounded its mate will almost invariably join it, and frequently allow itself to be approached and shot without attempting to escape. In some instances I have known a bird thus bereaved of its partner to remain in the vicinity for two to three days, calling and circling about" (Nelson 1887).

Because of the concentration of birds at Horseshoe Lake, individuals from a broken family that return to the shooting fields in search of missing members can seldom be identified. However, one such instance was observed by a hunting club owner in 1944. Four geese from the refuge swung over a pit and two were dropped; the two remaining flew back toward the refuge, and when over the lake they made a wide swing and came directly back over the same pit, where they also were shot.

In 1945, another incident was noted that demonstrated the high vulnerability of the surviving members of a broken family. A flock of five geese entered a shooting field and, as the birds approached the second pit, two of the flock were killed and one crippled. The two uninjured geese immediately alighted and remained with the cripple for about 10 minutes before taking flight toward the refuge lake. On their way to the lake, they were crippled, one being hit so severely it barely gained the refuge.

It is apparent from these examples of Canada goose behavior that the permanency of family ties offers one explanation why geese, unlike ducks, cannot easily be shot out of a field. Surviving members of broken families searching for mates, parents, or young that have been shot probably contribute appreciably to the total bag; thus, a high kill at a shooting club early in a hunting season may insure continuance of a high kill through the remainder of the season. The presence of the survivors over the shooting fields would tend to decoy unbroken families into gun range. As a result, the performance of the geese at some clubs toward the close of the hunting season might be aptly described as a perpetual-motion shooting gallery, the birds moving across the hunters' horizon in a never-ending procession against the heaviest kind of gunfire.

Sociability

The Canada goose is a social bird and, except during the breeding season, it tends to congregate in fairly large numbers. This tendency, which was common to some of our now extinct species of birds and mammals, often has two important undesirable results: first, under some conditions it causes the species to lose some of its normal wariness; and, second, when the remnants of a population band together they give an unwarranted impression of general abundance.

Audubon (1843) made the observation that the behavior of geese using small water areas may differ from that of flocks that resort to large bodies of water; that is, the behavior may vary according to relative densities on an area. "The Canada goose is less shy when met with far inland, than when on the sea-coast, and the smaller the ponds or lakes to which they resort, the more easy it is to approach them."

Apparently wariness is related both to the total size of an aggregation and its size in proportion to the area it uses. The first relationship may be of a psychological nature; many species of mammals and birds show a reduction in wariness when they are in large herds or flocks. It is fairly common knowledge that many species, for example the ruffed grouse, are very wild when at the bottom of their cycles but are quite readily killed when abundant. At Horseshoe Lake the wariness of the geese in the autumn decreases as the flock increases and spreads out over the refuge, thereby reducing the area of unoccupied ground to which disturbed flocks can retire.

While the loss of natural wariness in aggregations of wild game is serious from a long-term standpoint, the impression of abundance that local concentrations create in the minds of observers may serve as a fairly immediate threat to the future of a species since it becomes a premise for unlimited gun pressure. To substantiate this point we need only cite recent history of the flock at Horseshoe Lake. From 1942–43 to 1945–46 this flock had grown smaller each year, while most of the local residents and visiting hunters at Horseshoe Lake believed that each year there were "more than ever." To many hunters, a closed season on this flock in 1946 seemed to be a needless infringement of their privileges.

Hewitt (1921) has stated, "It should also be pointed out that when a formerly abundant animal becomes reduced in numbers the remnant may tend to herd together and thus give an impression locally of great abundance. . . . . *Local* abundance, therefore, should never be taken as an indication of *general* abundance, and as a reason for permitting killing in large numbers."

Jackson (1943) has stressed the dangers of overshooting local remnants: "Extinction in every case was probably brought about at first by gradual depletion of the population and through local extirpation. When the population becomes reduced to a danger point, extinction may come with unexpected rapidity. Dislike the assertion as we may, in recent times the human species has been the prime factor in the extermination of other species."

HISTORY OF GOOSE HUNTING IN ILLINOIS

The hunting of Canada geese was once common in widely scattered areas over the state of Illinois. In most of the areas that formerly offered considerable shooting, the hunting of Canada geese as a sport of any consequence has ceased to exist. In a few, goose hunting has continued on a smaller scale; only in the Horseshoe Lake area has the kill in most years been high. Because the history of the sport in Illinois parallels the history of many other goose-shooting areas in the flyway, and because it relates to present goose-management problems, it is briefly reviewed here.

Two factors have been chiefly responsible for changes in the methods of goose hunting, and for the decrease or increase of goose hunting in different sectors: (1) the development of state, federal, and private refuges, frequently attended by artificial feeding, and (2) the outlawing of both baiting and use of live decoys. Formerly, fair bags of Canada geese were made on the Big Foot Prairie in the northeastern portion of Illinois near the Wisconsin state line, but, with the establishment of a refuge and feeding station in southern Wisconsin, fewer birds have been available to northern Illinois hunters. The Putnam area, west of Lake Senachwine, in the Illinois River valley, yielded fair bags of geese until 1935, when both baiting and use of live decoys were prohibited. When feeding was curtailed, the area no longer proved attractive enough to hold flocks for sufficient time to provide hunting.

In about 1925, Mason County, bordering the Illinois River, was the most important goose-shooting area in Illinois. The use of live decoys in the fields of winter wheat situated near large bottomland lakes was responsible for the popularity of this area. Field-pen hunting of Canada geese at private shooting clubs and at commercial day-shooting "clubs" in this county was centered largely east of Clear and Chautauqua lakes, northeast of Havana, and between Bath and Snicarte.

The average kill of honkers in the Clear Lake area in the twenties is reported to

Fig. 47.—Before paved roads and the Horseshoe Lake Game Refuge brought the hunter and the Canada goose into close proximity, goose hunting in southern Illinois was a fairly arduous undertaking. Here is a party of well-equipped hunters on their way to a Mississippi River bar. This photograph was taken in Alexander County in the early twenties. (Photograph by Bob Becker.)

Fig. 48.—Canada goose hunting as it was carried out on the Mississippi River sand bars in southern Illinois before the creation of a refuge at Horseshoe Lake. (Photograph by Bob Becker.)

have been about 100 per year or roughly 7 to 10 per cent of the number reported to have lingered in that area in those years. The top kill in the Bath-Snicarte area by the Brownstone Club in 1928 was 514 geese, more than the combined kill of all the other clubs in that region. In the late twenties and early thirties the average kill at Brownstone was about 400 per year. After the prohibition of baiting and use of live decoys, commercial day-shooting in the Illinois River valley was at an end, and only one private club primarily for goose shooting still exists. The continuance of Canada goose hunting in Mason County is due largely to the operation of two refuge areas, one private and one federal, that holds the birds in the area. In recent years, kills in the entire Illinois River valley have been about 400 birds per hunting season.

The river bars and islands of the Mississippi River between Chester and Cairo, Illinois, have been a wintering ground for Canada geese for many years, and since pioneer days this area has been noted for the goose shooting it afforded. The recent concentration of geese at Horseshoe Lake is in marked contrast to the wide dispersal of the birds in earlier times. With the change in the type of wintering habitat, from one that was relatively primitive to one approaching parklike conditions, goose-hunting methods underwent an equally drastic change.

The following description is quoted from an unpublished report in 1941 by Arthur S. Hawkins, then of the Illinois Natural History Survey, and Paul S. Smith, then, as now, of the United States Fish and Wildlife Service.

Fig. 49.—Scene at goose-hunting club near Horseshoe Lake. The Horseshoe Lake region has been one of the most intensively hunted areas in the United States. The refuge totals only about 3,700 acres, but between 1941 and 1945 the area around it devoted to hunting averaged 11,000 acres controlled by an annual average of about 50 clubs. The number of pits and blinds in this acreage in the same period averaged approximately 400 and the total hunter capacity of the area 1,000.

At the beginning of the present century there were comparatively few goose hunters, because goose hunting was no sport for the novice. Most of the hunters were skilled river men; those who traveled to the hunting grounds by land did so by horse- or mule-drawn vehicles over many tiresome miles of nearly impassable roads, fig. 47. Once at the shooting grounds there remained the task of digging a pit and placing the decoys, fig. 48. After a hard day's hunt, the hunter either camped out on a bare sand bar or faced a long return trip. Although there were more geese and fewer hunters in those early days, real skill was required to bag geese consistently because the goose range was extensive and the sand bars numerous.

Then, as now, silhouettes or "shadows," as they are called locally, were used to decoy the geese. Live decoys were seldom

Fig. 50.—Modern-day goose hunters in a typical pit at a day-shooting club adjacent to the Horseshoe Lake Game Refuge.

Fig. 51.—Typical goose blind in a soybean field near the Horseshoe Lake Game Refuge.

used until after 1906, when it became the custom to use three live decoys in combination with the silhouettes. The silhouettes were arranged in V-formation, with the apex of the V downwind from the pit. A live "caller" was placed at the vertex and at each end of the V. In between were the "shadows." Bait was not used, but, in order to induce the geese to work into the proper bar, hunters sometimes placed "scarecrows" on adjacent bars.

Improved roads and faster transportation brought goose hunting within the reach of the masses, fig. 49. Heavy competition for the better hunting places ensued. The demand for more hunting grounds resulted in the development of field shooting.

Long before baiting came into prominence, goose hunters recognized that no other type of feed was more attractive to geese than a large field of fall-planted wheat or rye. As soon as the weather turned cold, however, shelled and ear corn, wheat kernels, cowpeas, and similar feeds, when properly scattered, proved very attractive to the geese, although their desire for greens continued.

When decoys were used, the usual procedure was to construct a pen using a roll or two of 3-foot wire. In this pen were placed as high as 100 geese. Usually one or more geese were separated from their mates so that they would "talk" back and forth to each other. Another trick was to place a trained goose, which was wing-clipped, in the blind; the goose was then thrown from the blind and permitted to walk to the pen, "talking" to its mate in the pen as it went. If the first decoy failed to entice a wild flock within the range of the gunner, others were released from the pit until the wild geese decoyed as desired, or the supply of decoys was exhausted. Only a small percentage of captive geese behaved in such a manner as to make good decoys. These geese became as valuable an aid in goose hunting as well-trained bird dogs are in quail hunting, and commanded equally high prices on the market. The function of live decoys was to attract the geese, while that of feed was to hold them and to encourage the birds to return again.

One answer to increased hunting pressure was the formation of goose hunting

Table 10.—Goose hunting regulations as they applied to Alexander County, Illinois, 1927–1945.

Year	Open Dates (Inclusive)	Number of Days	Time[1]	Bag Limit	Possession Limit	Live Decoys	Bait	Miscellaneous
1927	10/1–1/15	106	*a*	8	None	Yes	Yes	
1928	9/16–12/31	106	*a*	8	None	Yes	Yes	
1929	9/24–1/7	106	*a*	8	None	Yes	Yes	
1930	9/24–1/7	106	*a*	4	8	Yes	Yes	
1931	11/1–11/30	30	*a*	4	8	Yes	Yes	
1932	10/16–12/15	60½	*a*	4	8	Yes	Yes	
1933	10/16–12/15	60½	*a*	4	8	25	Yes by permit	
1934	10/6–1/13[2]	30	*b*	4	8	25	No	Duck stamp
1935	10/21–11/19	30	*c*	4	4	No	No	Duck stamp, 3-shell law
1936	11/1–11/30	30	*c*	4	4	No	No	Duck stamp, 3-shell law
1937	11/1–11/30	30	*c*	5	5	No	No	Duck stamp, 3-shell law
1938	10/15–11/28	45	*c*	5	10	No	No	Duck stamp, 3-shell law
1939	10/22–12/5	45	*c*	4	8	No	No	Duck stamp, 3-shell law
1940	10/16–12/14	60	*d*	3	6	No	No	Duck stamp, 3-shell law
1941	10/16–12/14	60	*c*	3	3[3]	No	No	Duck stamp, 3-shell law
1942	10/15–12/13	60	*e*	2	4	No	No	Duck stamp, 3-shell law
1943	10/15–12/13	60	*e*	2	4	No	No	Duck stamp, 3-shell law
1944	10/14–12/12[4]	60[4]	*f*	2	4	No	No	Duck stamp, 3-shell law
1945	11/24–12/31[5]	38[5]	*g*	2	4	No	No	Duck stamp, 3-shell law

[1] Shooting permitted: *a*—one-half hour before sunrise to sunset; *b*—sunrise to sunset, except that in 1934 on baited grounds closing time was 3 P.M.; *c*—7 A.M. to 4 P.M.; *d*—sunrise to 4 P.M.; *e*—sunrise to 12 noon; *f*—one-half hour before sunrise to 12 noon; *g*—12 noon to 4:30 P.M.
[2] Two days a week.
[3] Three in any 7 consecutive days.
[4] Or season limit of 6,000 geese (actually 21 days); by agreement of clubs, season began October 28 and was closed November 17. Information from V. C. Conover, Game Management Agent, United States Fish and Wildlife Service.
[5] Or season limit of 5,000 geese (actually 5 days).

clubs, but since the time of the Egyptian Hunting and Fishing Club, organized in 1904, goose clubs have changed considerably in Alexander County. Present-day clubs, with a few exceptions, are strictly commercial. In contrast, this first club (which had annual dues of only $5) was a nonprofit organization. At one time, it boasted a membership of 50, all local hunters. In 1941, there were at least two dozen clubs in Alexander County, each of which, according to a direct comparison of kill records, killed more geese annually than did the Egyptian Club.

Goose hunting first took on a commercial aspect when in 1913 a Chicago business man began to lease the sand bars most frequently used by the geese. By 1916, most of these bars were no longer open to public hunting. Up to that time field shooting had been scorned by most real goose hunters. Now that the river shooting was largely under the control of a few men it was field shooting or nothing for the old timers.

The purchase of Horseshoe Lake for a refuge in 1927 created a boom in commercialization of goose shooting. Mediocre farm lands located near the refuge suddenly commanded fancy prices. Now almost every field located around the refuge contains pits and blinds during the hunting season, figs. 50 and 51.

Data obtained from veteran hunters on the number of geese killed along the Mississippi River in the eighties and later have been too contradictory to permit any definite conclusions. None of the information obtained, however, indicates that the kills made in those early years exceeded recent kills at Horseshoe Lake. A summary of hunting regulations as they applied to geese in Alexander County is given in table 10. The relationship between number of hours of open season, number of geese bagged, and hourly kill per season is shown in figs. 52 and 53.

Neither the hourly bag nor the seasonal bag shows significant correlation with the number of hours open to hunting.

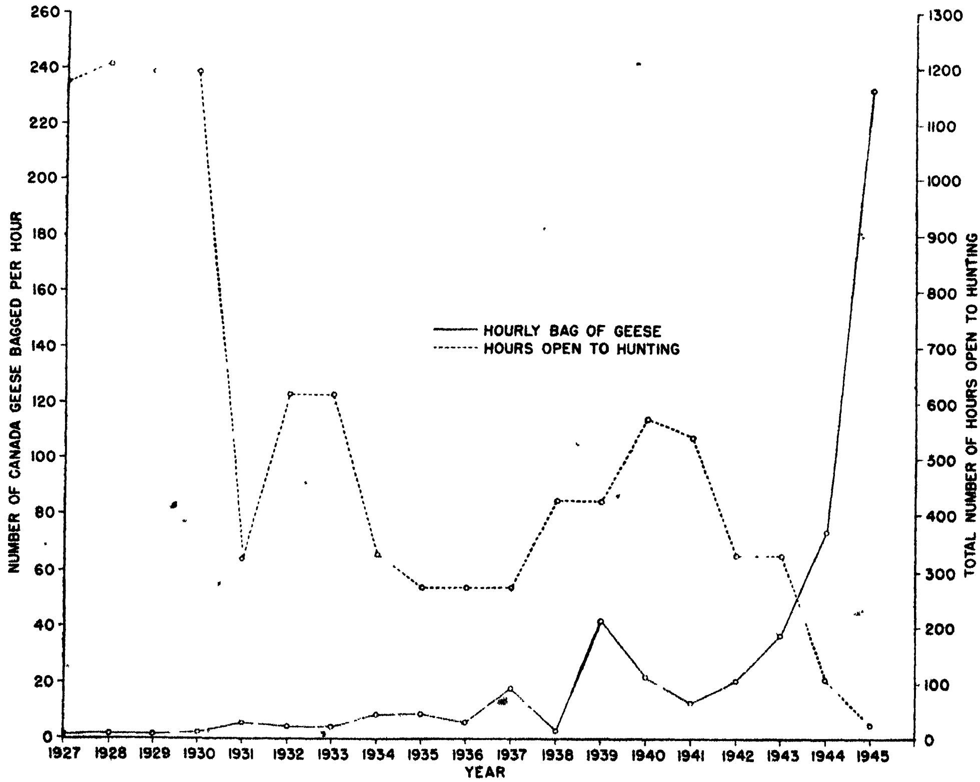

Fig. 52.—Hourly bag of Canada geese and number of hours open to hunting in Alexander County, Illinois, 1927–1945.

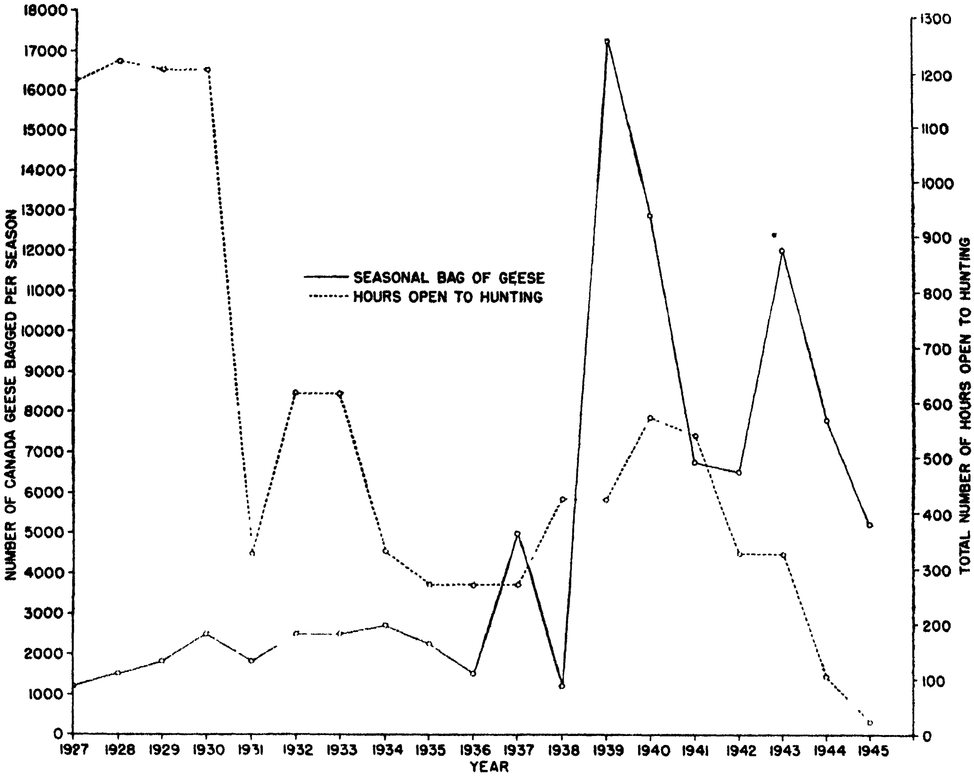

Fig. 53.—Seasonal bag of Canada geese and number of hours open to hunting in Alexander County, Illinois, 1927–1945.

ANNUAL BAG

In recent years the annual kill by hunters of Mississippi flyway Canada geese has probably exceeded losses resulting from any other single cause. The hunter kill includes the geese bagged and those so severely crippled by gunfire that they soon die.

Hochbaum (1944) has pointed out that the ratio of the number of hunters to ducks is such that it is mathematically possible for the licensed hunters legally to exterminate the continental duck population in one season. In the case of the Horseshoe Lake flock of Canada geese, the threat of extirpation has been real. If hunting in Alexander County, Illinois, had been permitted for the duration of the full 80-day waterfowl season either in 1944 or 1945, that population might have been reduced to a remnant, fig. 54.

Of all mortality factors, the bag by hunters is the one that can be most easily controlled to insure preservation of the Canada goose population. Insofar as management of Mississippi flyway Canada geese is concerned, the annual bag has two subdivisions: the bag made by Indians on the breeding grounds in Canada, and the bag made by hunters in southern Canada and the United States while the geese are in migration or in the vicinity of the wintering areas.

On Breeding Grounds

Man is believed to be the predator taking the heaviest toll of Canada geese on the breeding grounds. Responsible for the bulk of the take in the James Bay area are the Cree Indians, natives of the region; the handful of white residents also kill a few geese. Food is the primary consideration for killing geese in the North; any sport involved only adds flavor to the undertaking.

In the James Bay and Hudson Bay area the native populations are dependent on

waterfowl as one of the few reliable sources of meat; big game animals are usually scarce and small game is subject to violent cyclic fluctuations in numbers. The importance of waterfowl, particularly geese, to the Cree Indians in former years can be readily realized from Barnston's report (1862). He estimated the annual kills of all species of geese on the west coast of James Bay and the south coast of Hudson Bay as follows: Moose Factory district, 10,000 annually; York Factory and Churchill district and region to the north, 10,000; Fort Albany district, 17,000 to 20,000 in the autumn and 10,000 in the spring; Fort Severn district, 10,000.

The species of geese that made up the bag at these posts must have varied considerably then as they do today. We have no data regarding Churchill, but we conclude from Barnston's report that the white-fronted goose was shot in fair numbers by the Churchill Indians. It seems certain that snow geese and lesser Canada geese also contributed to the total kill in that area. In recent years at Moose Factory, Fort Albany, Attawapiskat, figs. 55 and 56, and Weenusk, the annual kill of geese has consisted chiefly of blue geese and snow geese, with Canadas running a poor third. At Fort York, the annual kill of Richardson's geese, *Branta hutchinsii,* equals the combined kill of snow, blue, and Canada geese; the Canadas are outnumbered in the native hunter's bag at this post by the "wavies."

Fig. 54.—The registered kill of Canada geese (1,400) on opening day at hunting clubs near Horseshoe Lake in 1945 was approximately equivalent to the number of geese shown in this illustration. (Photograph taken at the Horseshoe Lake Game Refuge by George W. Sommers.)

Big game represents an unpredictable source of food for the present-day Indian. In the early part of this century, caribou,

Fig. 55.—Attawapiskat, Ontario, summer, 1947. The Cree Indians of the James Bay region gather at such coastal posts as this soon after the breakup of the rivers in spring. In late summer or autumn they return to their inland trapping grounds. Those who trap far inland leave before the autumn hunt for blue geese and snow geese begins along the coastal marshes.

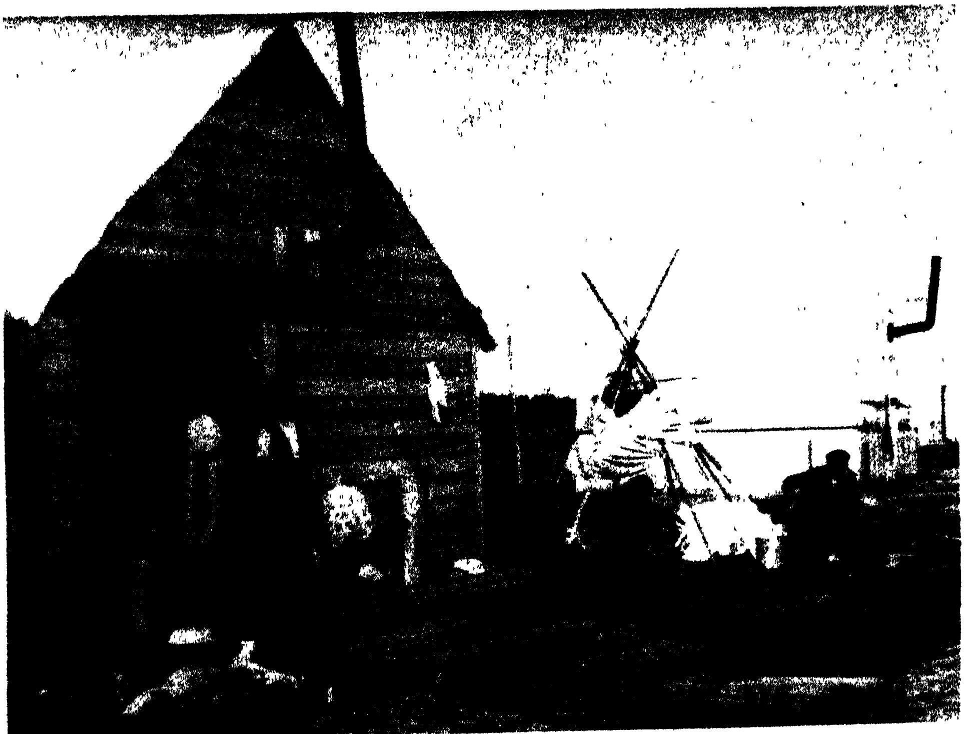

Fig. 56.—Summer scene at Attawapiskat. After a long winter of arduous trapping and hunting, often entailing considerable hardship, the native Indians are usually content to summer quietly at or near the coastal trading posts.

perhaps the barren-grounds type, migrated along the west coast of Hudson and James bays as far south as Fort Albany. They are now gone except for a small band at Cape Henrietta Maria, which may represent remnants of this migratory group. Woodland caribou are found scattered over the muskeg country in small bands, but their total numbers are not great. Moose, always quite abundant in the country just south of James Bay, were scarce in the muskeg belt lying west of the bay until 1946 and 1947, when there was an unprecedented influx of these animals, presumably from the south and west. On the whole, however, except for the waterfowl he kills in spring and autumn, the James Bay Indian must rely on small game, such as snowshoe hares, muskrats, grouse, and ptarmigan for his meat supply. When these cyclic species fail he is usually in dire straits. Barnston (1862) wrote:

When the long and dreary winter has fully expended itself, and the willow grouse *(Tetrao Saliceti)* have taken their departure for more northern regions, there is frequently a period of dread starvation to many of the natives, who are generally at that time moving from their wintering grounds to the trading posts. The first note, therefore, of the large gray or Canada goose *(Anser canadensis)* is listened to with a rapture known only to those who have endured great privations and gnawing hunger. The melancholy visages brighten, and the tents are filled with hope, to which joy soon succeeds, as the happy father, or the hopeful son and brother, returning successful from the hunt, throws down with satisfaction and pride the grateful load.

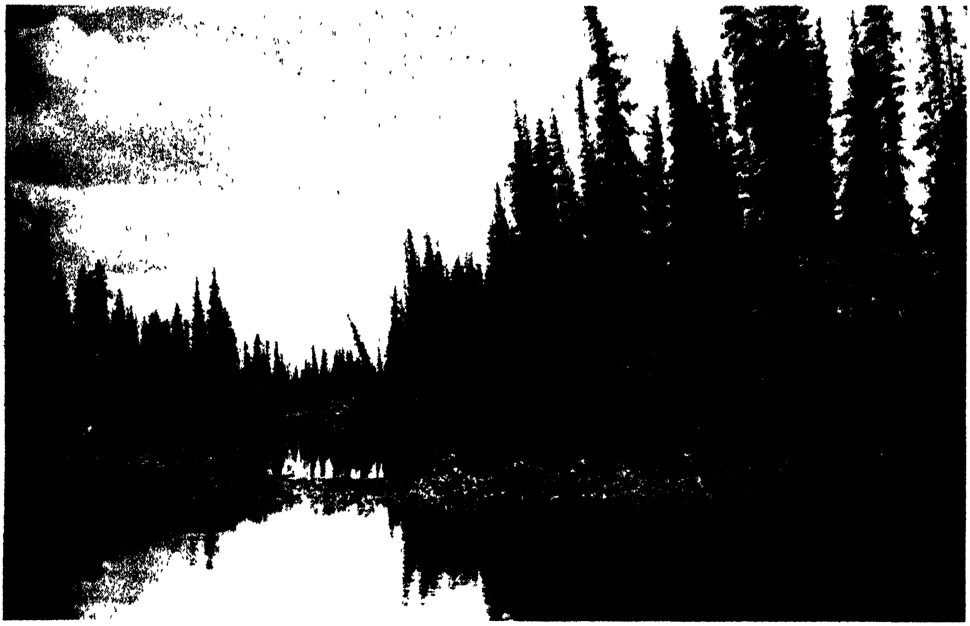

Fig. 57.—Through the establishment of a system of preserves and regulated trapping, beaver populations in the Hudson-James bay region are gradually being restored to former levels. Besides furnishing many pounds of highly nutritious meat and thereby reducing the hunting pressure by Indians on waterfowl, beavers also improve the character of small streams as brooding areas for Canada geese. This illustration shows a beaver dam on Little Partridge Creek, which empties into the southwest corner of James Bay. The tall trees that border the stream are black spruce; the principal shrubs are willow, alder, and sweet gale.

Although the economic plight of the Indian has been gradually improved from those early times, particularly in recent years, through Dominion government family allowance, government relief, and liberal credit at the fur posts, the first

arrival of geese in the spring is always an event of great importance. Bishop Robert J. Renison of the Diocese of Moosonee relates one of the highlights of his early years as Anglican minister at Fort Albany. A funeral service had just been held at the small church and the mourners, cold, sick, discouraged, and hungry after a long winter, were moving on snowshoes toward the cemetery (Renison 1944).

The Missionary walked in front, treading warily among the tents where husky dogs prowled, on his way to the little grave yard where two men with pickaxes had been for hours chipping the frozen earth deep enough to make a shallow trench. Although in the morning the whole scene looked and felt like the ragged end of winter, now the South wind grows warmer every moment and already the haze is seen in quivering waves over the melting ice and snow.

As the cortege was lost in the maze of wigwams, suddenly the cry of wild geese was heard. The funeral procession stood still and from all over the settlement came the answering call from every living soul. A great flock of Canada grey geese swept like a gigantic airplane over the trees rejoicing at what seemed a welcoming call. The phalanx turned to leeward and sailed slowly down over the spot from which the sounds came. It was too much even for sorrow and decorum. The Chief Mourner dived into his tent and appeared in a moment with his loaded gun. With incredible ease and grace he brought down a goose with each barrel. Cheers and laughter rang out. The oldest instinct of man triumphed in every simple heart and as the pallbearers patted the bereaved husband on the back, he modestly replied like a true sportsman, "She did it. I always had luck when she was with me." Then the spell was broken; the procession resumed its direction.

The recent increase of beaver through restocking and the establishment of beaver preserves on the west side of James Bay will, now that trapping is open, add thousands of pounds of highly nutritious meat to the Indian food resources, fig. 57. Since beaver and most of the Canada geese are secured in early spring, beaver restoration will materially reduce the annual toll of geese. This shift in hunting pressure is reported to have taken place in the Rupert House country where beaver trapping has recently been on a sustained-yield basis.

The spring kill of the Canada goose west of James Bay takes place inland when the Indians are still on their trapping grounds and the rivers are frozen over. Hunting is done from blinds or stands built of brush and set out on the

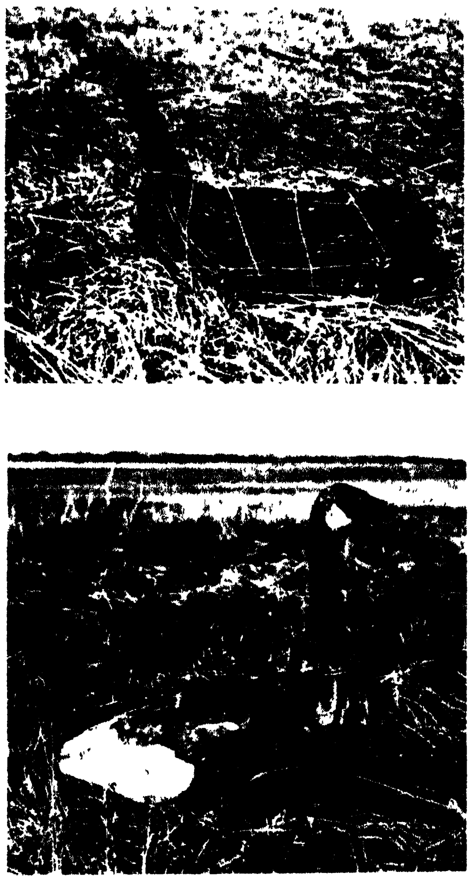

Fig. 58.—Decoys made by Cree Indians hunting in Hannah Bay at the south end of James Bay. The decoy in the top picture was made of willow twigs; the lifelike decoy in the lower picture was made from a log and a charred stick.

river ice. Decoys made of willow twigs or small stumps or blocks of wood of proper size are set up in such a way as to bear a crude resemblance to a flock of sitting geese, fig. 58. Often using inferior arms with hand-loaded shells, the native hunters easily overcome the handicaps of poor equipment by their expert ability to call geese, an art practiced from

childhood. In late summer, some of the Indians supplement their meager diet by hunting ducks along the coast, fig. 59, while in autumn most of the hunters are in the coastal marshes for blue geese and native hunters with the aid of an interpreter, fig. 60. In some cases it appeared that the hunter questioned could remember his exact bag of the current year and of the previous year. In many other cases,

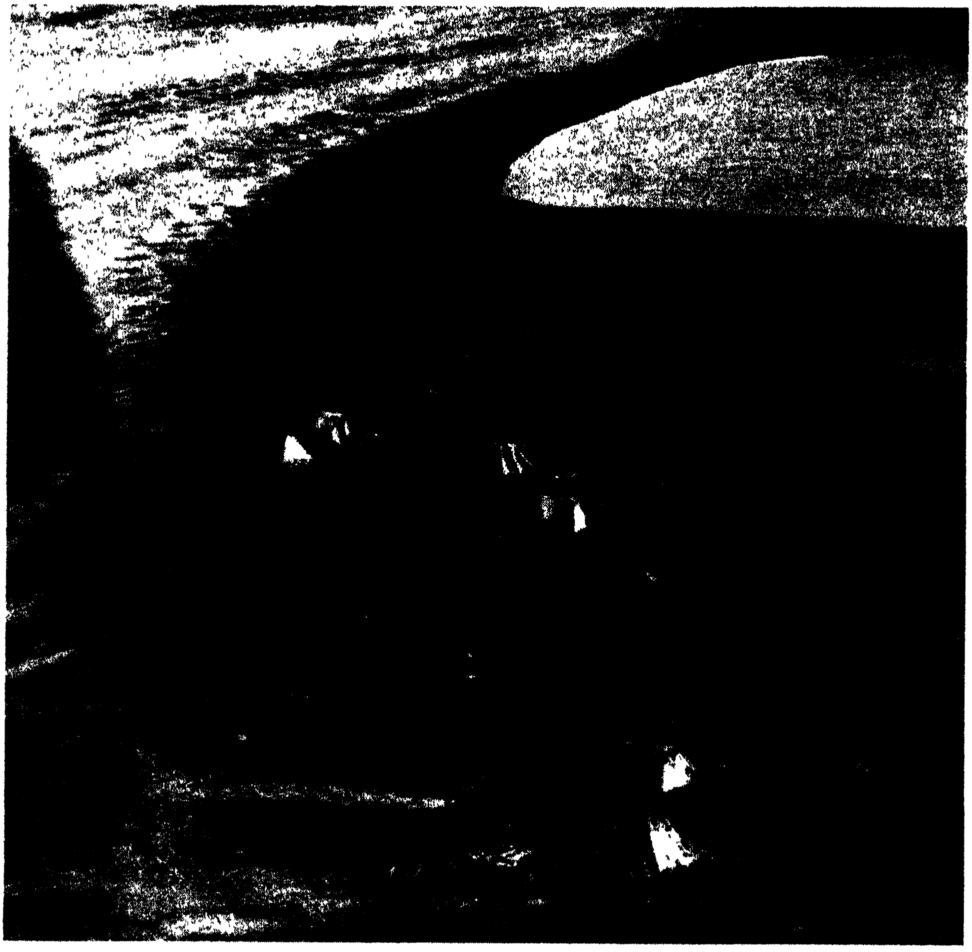

Fig. 59.—Indian encampment on Cape Henrietta Maria. The Indians of this group trade at the Lake River outpost, but visit Attawapiskat briefly in the summer. Before autumn, they return to the cape to hunt waterfowl.

snow geese, hoping to accumulate a supply of meat for at least a part of the winter. Any Canada geese killed at these times are incidental to the hunt for "wavies," as then the latter outnumber the Canadas along the coast by the ratio of many hundred to one.

Our bag data were secured from post managers and other informed residents and through direct questioning of the it was equally obvious that the hunter could remember only the approximate number of geese killed and bagged, as he gave figures in multiples of 5 or 10. The inherent tendency to exaggerate in giving "rounded off" figures introduces considerable error. Therefore, we believe that the data in table 11 may exceed the actual bag by perhaps 10 to 15 per cent.

A few Indians, fortunate enough to

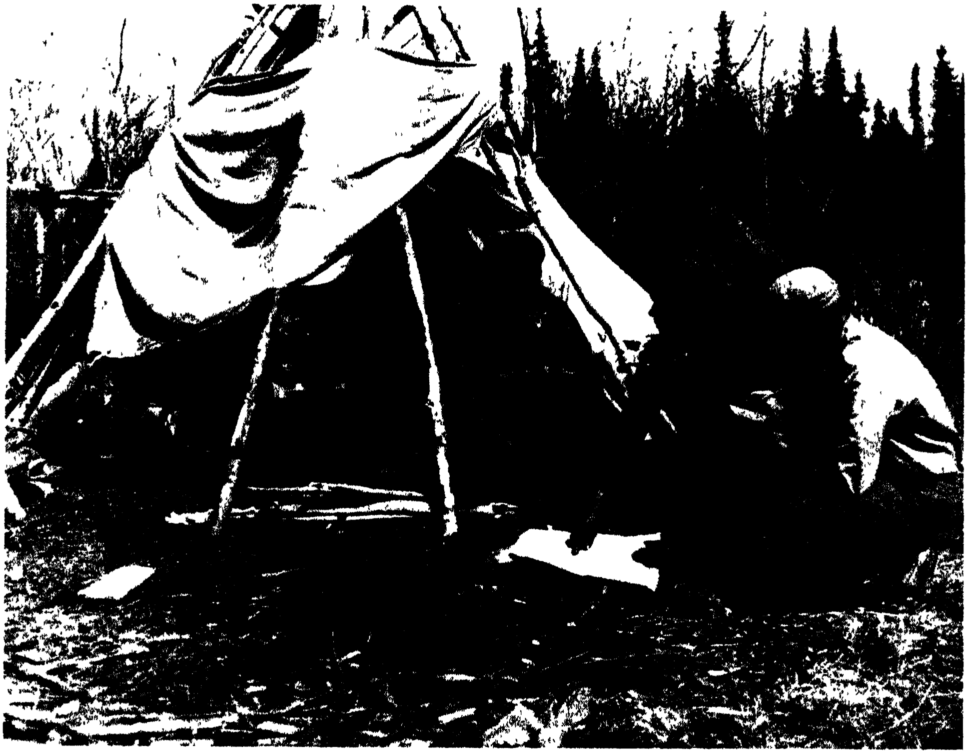

Fig. 60.—The number of Canada geese killed by Indians was calculated from information secured through personal interviews with native hunters. The hunter being questioned here, with the aid of an interpreter, is a member of the Ogoki band. Sixteen hunters of this band were interviewed in 1946 and the same number the following year. The total number of Cree hunters interviewed was 94 in 1946 and 171 in 1947.

Table 11.—Number of Cree Indian hunters, average bag per hunter, and total calculated bag of Canada geese by native hunters residing in the breeding range of the Mississippi Valley goose population, 1946 and 1947.

Fur Trade Post and Indian Trapping Territory	Total Number of Hunters	Number of Hunters Interviewed		Average Bag per Hunter Interviewed		Calculated Bag per Trapping Territory	
		1946	1947	1946	1947	1946	1947
Ogoki	16	16	16	3.0	3.6	48	56
Fort Albany (including Kapiskau and Ghost River outposts)	100	24	67	9.5	11.1	950	1,110
Attawapiskat[1] (including Lake River outpost and Akimiski Island)	134	28	31	13.3	15.6	1,782	2,090
Weenusk	33	—	31	15.0[2]	19.0	495	627
Fort Severn	47	26	26	14.0	17.0	658	799
Total	*330*	*94*	*171*	*65.0*	*66.3*	*3,933*	*4,682*
Average	....	....	....	13.0	13.1	—	—

[1] The bag at Attawapiskat in 1948 was 1,720 according to Dr. John Honigman, resident anthropologist at the post that year (personal communication).
[2] An estimate, based on data for later year.

have their trapping grounds located in good Canada goose hunting territories, bag as many as 45 geese per hunter, while other Indians, located in poor goose habitat, take only a few geese or none. In 1944, when the inventory showed that there were approximately 66,000 geese in the Mississippi flyway, the estimated bag on the breeding grounds was 5,500, or about 8 per cent of the number of birds believed to have been available to the Indians in the spring of that year. In 1946 and 1947, the calculated bag, table 11, represented about 10 and 9 per cent, respectively, of the total population available in the springs of those years, table 7. Band recoveries, on the other hand, indicate that the annual bag of the natives is about 5 to 6 per cent of the available population. Taking into consideration the kind of error inherent in these data, it would seem that the Indians do not kill more than 10 per cent of the Canada goose population that reaches the breeding grounds in the spring.

The time of kill of Canada geese by Indians on the breeding grounds is indicated in fig. 61.

Southern Canada and United States

Available data on the goose bag in the United States and in southern Canada are very unsatisfactory. Goose bag records from Illinois are more nearly complete

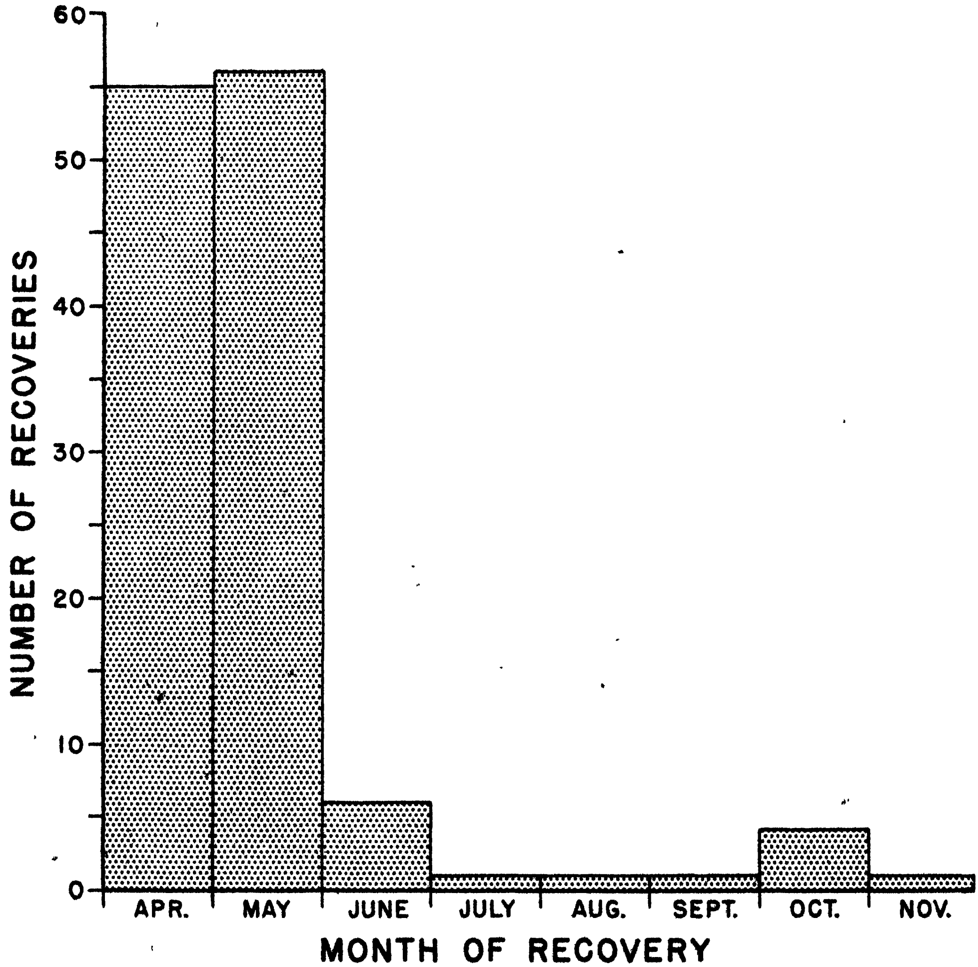

Fig. 61.—Time of kill of Canada geese by Indians on the breeding grounds, as shown by recovery records, 1941–1947, of geese banded at the Horseshoe Lake Game Refuge.

Table 12.—Estimated bag of Canada geese in regions frequented by the Mississippi Valley population, 1941–1945.

Province, State, or Other Area	Low Annual Bag	High Annual Bag	Estimated Mean Bag
West coast of James Bay	3,950	5,500	4,700
Ontario, exclusive of James Bay region	100	700	400
Minnesota	100	300	200
Wisconsin	450	850	620
Michigan	1,000	5,000	2,000
Indiana	1,000	2,000	1,500
Illinois	5,250	18,400	8,400
Ohio	?	?	200
Iowa	50	100	75
Missouri	150	400	260
Arkansas	200	400	300
Kentucky	25	100	50
Tennessee	50	150	100
Mississippi	50?	800	400
Louisiana (eastern part only)	?	?	150
Total	*12,375*	*37,700*	*19,355*

than those from any other state, in part because of a law that requires all licensed clubs to keep daily records of their take and in part because only a small number of areas in the state afford goose hunting. Most states in the flyway, however, attempt to calculate the take, either from report cards attached to the hunting licenses (the cards are designed to be mailed to a state official at the end of the season) or from data obtained from questionnaires sent to a sample of the licensed hunters. A few states make no attempt to secure bag data.

Bag data based on the hunter-report-card system are apt to be exaggerated. Studies made by Bellrose (1947) have shown that the state-wide bag of ducks in Illinois calculated from report cards is several times the actual bag. In Wisconsin, the calculated bag of Canada geese for two counties has been from 3.5 to 4.6 times the actual bag (see section on Wisconsin, below). Furthermore, as many states do not record the goose bag by species, the actual portion of the calculated bag that consists of Canada geese can only be estimated.

Table 12 summarizes our information on the Canada goose bag in recent years in those regions that lie in the Mississippi flyway. A more detailed analysis of the bag follows.

Southern Ontario.—In spite of the fact that the Miner Sanctuary, at Kingsville, in Essex County, has been a heavy concentration point for Canada geese for over 20 years, no commercial shooting clubs have operated in the fields surrounding the sanctuary. All of the hunting in the Kingsville area is reported to be flight shooting from public roads as the geese go to and from the sanctuary and their roosting grounds on Lake Erie.

The number of banded geese reported taken in this area does not indicate the true size of the bag since some of the local shooters do not appreciate the importance of the banding program at the Miner Sanctuary and do not report the bands they recover.

When live decoys and baited fields were permitted, the autumn bag in Essex County was about 1,000 birds, but, since these practices were outlawed, the bag has probably not exceeded 500 and frequently is as low as 200 or 300 birds. We are informed that the 1945 kill was unusually low, not over 50 geese.

We are told that near the Miner Sanctuary it is possible to bag geese easily only on days when there is a heavy overcast and a strong wind is blowing, thus causing the geese to fly low. On most days the geese are reported to be well out of gun range when they pass over the hunters who shoot on the perimeter of the protected area, the radius of which extends 1 mile beyond the sanctuary property.

Table 13.—Recoveries in the Mississippi flyway,* 1925–1944, of Canada geese banded each autumn and winter at Kingsville, Ontario.

State	Recoveries by 5-Year Periods								Total	
	1925–1929		1930–1934		1935–1939		1940–1944			
	Number of Recoveries	Per Cent of Total Recoveries	Number of Recoveries	Per Cent of Total Recoveries	Number of Recoveries	Per Cent of Total Recoveries	Number of Recoveries	Per Cent of Total Recoveries	Number of Recoveries	Per Cent of Total Recoveries
Michigan	8	8.4	36	13.0	30	18 6	57	19.5	131	15.9
Wisconsin	4	4.2	3	1.1	2	1.2	3	1.0	12	1.4
Minnesota	0	0.0	0	0 0	0	0 0	0	0.0	0	0.0
Ohio	14	14 6	28	10 1	8	5 0	26	8.9	76	9.2
Indiana	13	13 5	15	5.4	9	5 6	28	9.6	65	7.9
Illinois	34	35.4	143	51 8	61	37.9	131	44 7	369	44.7
Iowa	0	0 0	0	0 0	1	0.6	1	0.3	2	0 2
Kentucky	8	8 3	23	8 3	15	9 3	11	3.8	57	6.9
Tennessee	7	7 3	12	4 4	13	8 1	13	4.4	45	5.4
Missouri	5	5.2	9	3 3	17	10.6	15	5.1	46	5.6
Mississippi	1	1 0	1	0.4	1	0 6	1	0.3	4	0 5
Arkansas	2	2.1	6	2.2	0	0 0	5	1 7	13	1 6
Louisiana	0	0.0	0	0 0	4	2 5	2	0.7	6	0 7
Total	*96*	*100.0*	*276*	*100.0*	*161*	*100.0*	*293*	*100.0*	*826*	*100.0*

* Recoveries made in central and eastern Ohio, Kentucky, and Tennessee would be at the expense of the Southeast population.

We have no data on bags elsewhere in Ontario, but recoveries indicate that relatively few geese are shot between James Bay and the Miner Sanctuary. According to Dr. C. H. D. Clarke of the Ontario Department of Mines and Resources, very little goose hunting is now carried out along the east shore of Lake Huron. Formerly the use of live decoys in this area provided fair shooting. The average annual bag of Mississippi flyway geese in southern and western Ontario is estimated to be about 400.

Illinois.—More Canada geese of the Mississippi flyway are bagged in Illinois than in any other state in the wintering grounds. Recoveries of Miner autumn-banded geese show 45 per cent from Illinois; recoveries of Horseshoe Lake bandings show 60 per cent from Illinois, tables 13 and 14.

Most of the geese bagged in Illinois are shot in the Illinois River valley and Alexander County; only a few geese are shot in other sections of the state. From a knowledge of kills at the principal goose-shooting clubs and from information gained through talks with sportsmen, Frank C. Bellrose of the Illinois Natural History Survey placed the average annual bag in the period covered by this report at 1,100 birds for the Illinois River region and the rest of the

Table 14.—Recoveries within the wintering range of the Mississippi Valley population of Canada geese banded at Horseshoe Lake, 1940–41 through 1944–45.

State	Number of Recoveries*	Per Cent of Total
Michigan	20	8 9
Wisconsin	23	10 2
Minnesota	2	0 9
Ohio	2	0 9
Indiana	7	3 1
Illinois	135	60 0
Iowa	5	2 2
Kentucky	3	1 3
Tennessee	2	0.9
Missouri	14	6.2
Mississippi	2	0.9
Arkansas	1	0.5
Louisiana	9	4.0
Total	*225*	*100.0*

* Exclusive of recoveries the season of banding. Table also includes several recoveries for which exact locality data were unknown. Bands recovered in Missouri were in counties close to Horseshoe Lake and were probably from geese belonging to the Horseshoe Lake flock.

Table 15.—Annual shooting losses of Canada geese in the region of Horseshoe Lake, 1941–1945.

Hunting Season	Reported Bag by Licensed Clubs in Alexander County	Estimated Bag on Non-Club Grounds in Alexander County	Bag in Cape Girardeau, Scott, and Mississippi Counties, Mo.	Total Number of Geese Bagged*	Crippling Loss at 30 Per Cent of Total Bag	Estimated Illegal Bag	Approximate Total Loss
1927				1,200			
1928				1,500			
1929				1,800			
1930				2,500			
1931				1,800			
1932				2,500			
1933				2,500			
1934				2,700			
1935				2,250			
1936				1,500			
1937				5,000			
1938				1,200			
1939	17,300	?	?	17,300			
1940	12,900	?	?	12,900			
1941	6,524	100	150	6,774	2,032	150	8,956
1942	6,279	100	150	6,529	1,958	150	8,637
1943	11,162	600	300	12,062	3,618	300	15,980
1944	7,157	250	400	7,807	2,342	400	10,549
1945	4,444	500	300	5,244	1,573	300	7,117
Total.				*95,066*			
Total last 5 years	35,566	1,550	1,300	38,416	11,523	1,300	51,239

* Bags for 1927–1938 estimated by Paul S. Smith from information gathered from club owners and others familiar with the area. Bags for 1939–1945 from club records.

state exclusive of the Horseshoe Lake area. The bag figures for the Horseshoe Lake area, which are much larger, are given in table 15. On days when the geese traded back and forth between the refuge and outside areas, particularly when the food supplies at the refuge were exhausted, most hunters having blinds or pits near the refuge secured their limits.

Michigan.—Michigan is probably second only to Illinois in its take of Canada geese of the Mississippi flyway. More bands from autumn-banded Miner geese were recovered in Michigan, 1925–1944, than in any other state except Illinois, table 13. Also, band recoveries indicate that, during the past 20 years, Michigan has harvested increasingly larger percentages of that portion of the Mississippi flyway population that migrates between the Kingsville, Ontario, region and Lake Michigan.

Although hunters in Michigan are required to report their annual bags of geese, they are not asked to denote the species bagged. Consequently, the state-wide bags computed from hunter reports, table 16, include blue geese and snow geese, as well as Canada geese. Except for years when blues and snows linger on their flight south, Canada geese represent about two-thirds of the yearly kills, ac-

Table 16.—State-wide bag of all species of geese in Michigan, as calculated from hunter reports, 1938–1945. Data furnished by the Michigan Department of Conservation.

Year	Calculated Bag
1938	3,902
1939	6,635
1940	5,296
1941	5,921
1942	2,899
1943	6,567
1944	7,220
1945	23,129

cording to H. J. Miller of the Michigan Department of Conservation.

The figures given in table 16 are not comparable from year to year, because between 1938 and 1944 the number of licensed hunters sending in bag reports to the Department of Conservation dropped from 65 to 20 per cent. Because successful hunters are more apt to turn in their report cards than unsuccessful hunters, the accuracy of the computed kill varies from year to year. Excluding from table 16 the probable bag of blue geese and snow geese and taking into consideration exaggeration inherent in calculating statewide bags from hunter report cards, we estimate that the annual kill of Canada geese in Michigan from 1938 through 1944 was between 1,000 and 3,000 birds. In 1945, the total calculated bag of all species of geese was more than 23,000. Of this number, well over half consisted of blue geese and snow geese (Dr. Miles D. Pirnie of Michigan State College, personal communication) that failed to make their usual rapid southward migration and that were observed and shot in unusual numbers. The large number of banded geese reported shot in Michigan in the autumn of 1945 does, however, furnish undeniable evidence that there was a large increase in the total bag of Canada geese in that year over the number bagged between 1938 and 1944. Of 20 Canada geese banded at Horseshoe Lake between 1940–41 and 1944–45 and bagged in Michigan, table 14, 13 were bagged in the autumn of 1945.

The following Michigan counties, which are in the vicinity of important autumn concentration points and wintering areas, yielded the largest bags of geese of all species: Chippewa County in the northern peninsula; Leelanau County in the northwest sector of the lower peninsula; Huron, Tuscola, and Bay counties bordering Saginaw Bay; and Allegan, Kalamazoo, Barry, Berrien, and Calhoun counties in the southwestern lake section. According to Dr. Miles D. Pirnie of Michigan State College (personal communication in 1945) between 500 and 1,000 Canada geese were bagged within a 20-mile radius of the W. K. Kellogg Refuge, Barry and Kalamazoo counties, in 1944.

Various counties represented by 159 banded Canada geese shot in Michigan, 1925–1944, are shown in table 17.

Table 17.—Recoveries of Canada geese in Michigan, 1925–1944, banded at Horseshoe Lake, Illinois, and at the Jack Miner Bird Sanctuary, Kingsville, Ontario.

County	Number of Recoveries	County	Number of Recoveries
Allegan	31	Presque Isle	2
Berrien	16	Alpena	2
Barry	13	Benzie	2
Huron	12	Lenawee	1
Kalamazoo	12	Livingston	1
Calhoun	11	Otsego	1
Sanilac	10	Gratiot	1
Monroe	5	Gladwin	1
St. Joseph	5	Grand Traverse	1
Van Buren	4	Saginaw	1
Chippewa	4	Roscommon	1
St. Clair	4	Luce	1
Mackinac	3	Kent	1
Cass	3	Oscoda	1
Washtenaw	2	Lapeer	1
Wayne	2	Eaton	1
Newaygo	2	Lake	1
Total recoveries			*159*

Whatever the actual bag of Canada geese is in a given year in Michigan, it probably is not all at the expense of the Mississippi flyway population, as some geese belonging to the Southeast population undoubtedly are bagged as they migrate down the eastern edge of the state.

Wisconsin.—Band recoveries, table 14, indicate that Wisconsin is second only to Illinois in the toll its hunters take of the Horseshoe Lake flock. The largest kills of Canada geese in Wisconsin are made in Rock and Walworth counties, in the vicinity of the Rock County Refuge.

Geese in the Rock-Walworth county area show little of the tameness exhibited by the Horseshoe Lake flock. On leaving the refuge on the upland prairie for their roost lakes, they are said generally to spiral high up out of gun range before crossing over its boundaries, thus accounting in part for the relatively small kill, which is equivalent to about 8 per cent of the geese that are present in these two counties in late autumn and winter.

Careful estimates of annual bags in the Rock County Refuge area by personnel of the Wisconsin Conservation Department and the United States Fish and Wildlife Service, 1940–1945, did not exceed 400 birds; the average annual bag was considerably less. Wisconsin Conservation Department estimates for the probable and maximum Canada goose bags in these counties are as follows:

1940—200
1941—75, not exceeding 150
1942—317, not exceeding 400
1943—150, not exceeding 200
1944—40, not exceeding 50
1945—350, not exceeding 400

When the above estimates are compared with the bags calculated from hunters' report cards (1940, 732; 1941, 581; 1942, 1,445; 1943, 629), it appears that the annual calculated bags are exaggerated 3.5 to 4.6 times. These calculated bags are derived from a sample of the kill cards sent in by about 35 per cent of the licensed hunters. If the calculated state-wide bags reported by the Wisconsin Conservation Department are exaggerated to the same degree as are bags for Rock and Walworth counties (3.5 times), the corrected state-wide annual bag of Canada geese in Wisconsin between 1932 and 1944 has averaged about 500 birds and varied from about 170 (1935) to 860 (1942). If our method of estimating the state-wide bag is sound, it appears that the annual kill of Canada geese in Wisconsin has seldom approached the thousand mark.

Important kills have also been reported for Waushara County. The bag in this county in 1942 was estimated by Zimmerman (1942) to be 400. The total number of migrant geese that offered shooting to hunters in this area is unknown.

Minnesota.—Most of the Canada goose hunting in Minnesota is said to occur in the western third of the state, especially during the wet years. Kills in the eastern sections rarely occur, so that the total bag of the Mississippi flyway geese in Minnesota is probably small. The lack of band recoveries from eastern Minnesota substantiates this belief. From 1935 through 1944, the computed state-wide bags of all species of geese, based on reports received from 10 per cent of the hunters, ranged from 1,869 to 5,050 birds. As in Michigan, the 1945 calculated bag for all geese was the largest on record, 10,908.

Ohio.—We have few kill data for Ohio other than band recoveries. The principal kills of importance to Mississippi flyway geese would be those made in the region of Lake St. Marys. Kills made in central and eastern Ohio would be primarily at the expense of the Southeast flyway geese. We have arbitrarily placed the bag of Mississippi flyway Canada geese in Ohio at 200 per annum.

Indiana.—According to William B. Barnes of the Indiana Department of Conservation, goose hunting in Indiana is heaviest in the Kankakee region of northwestern Indiana and in the lake district to the east. As the flights move through northern Indiana to the southwest, additional shooting is provided in the Wabash River valley. Hunting pressure in this state appears to be, on the whole, relatively moderate. Of the total number of recoveries of geese banded at the Miner Sanctuary during the autumn in the past 20 years, approximately 8 per cent have been from Indiana, table 13.

At Hovey Lake Refuge about 300 Canada geese are generally present during the open hunting period, and the largest bag in any one season in a 5-year period, 1940–1944, was only five birds, 1.6 per cent of the flock. Partly responsible for this small bag was the wildness exhibited by the geese in the refuge vicinity.

Judging from questionnaire answers received from hunters by the Indiana Department of Conservation, it is doubtful if the kill of Canada geese in Indiana in recent years has ever greatly exceeded 2,000 birds and probably in most years the kill is considerably less than this figure.

Iowa.—According to Bruce F. Stiles of the Iowa State Conservation Commission, the yearly kill of Canada geese in Iowa is about 1,200 birds. He states that the heaviest migration is down the Missouri River valley. As band recoveries indicate that central and western Iowa is well west of the migration routes of the Mississippi flyway population, only a small portion of the above kill would be at the expense of this population. The paucity of band recoveries from eastern Iowa,

tables 13 and 14 and figs. 13–21, signifies that few Mississippi flyway geese migrating through this sector of the state stop en route long enough to afford much shooting.

Missouri.—The Missouri Conservation Commission estimates that, prior to the establishment of the Horseshoe Lake Game Refuge, approximately 75,000 Canada geese wintered on the sand bars and islands of the Mississippi River between Ste. Genevieve and Caruthersville, Missouri. Band recoveries, table 13, with the exception of returns from 1935 through 1939, indicate no pronounced change in the Missouri kills in relation to the Illinois kills since 1925. Before 1941, when the geese using the Horseshoe Lake Game Refuge were reported to have made daily flights to the river bars, considerably larger kills are said to have been made in Cape Girardeau, Scott, and Mississippi counties than in more recent years. Band-recovery data indicate that this period of higher kills was between 1935 and 1939. The yearly bags, estimated for the above counties by Paul S. Smith, are given in table 15. According to information received from M. O. Steen of the Missouri Conservation Commission, the annual bags in Missouri in the region of Cape Girardeau, Scott, and Mississippi counties averaged approximately 175 geese in recent hunting years.

State-wide annual bags, 1943–1945, are estimated to have been less than 400 birds. Besides the bag in southeastern Missouri, about 125 geese were killed on the Missouri River between Booneville and Jefferson City in central Missouri, and approximately 100 were killed in the vicinity of Swan Lake National Refuge in the north central part of the state. However, on the basis of present evidence, it would appear that the geese killed in central Missouri belong to the Eastern Prairie population and are not Mississippi flyway birds. Considerable numbers of Canada geese are reported to migrate through central and southwestern Missouri in the autumn, and it seems reasonable to conclude that they winter in western Louisiana and eastern Texas.

Kentucky. — Little information is available in regard to the state-wide kill in Kentucky, though band recoveries indicate that only the kills made in the western portion of the state would be from the Mississippi Valley population. Band recoveries show that since 1940 the annual bag of Mississippi Valley geese in this state has been greatly reduced, table 13. In 1939 and 1940, Paul S. Smith estimated that about 100 geese from the Horseshoe Lake flock were bagged in Kentucky; in more recent years, band recoveries and the findings of reliable observers indicate that very few geese from the Horseshoe Lake flock have been shot in Kentucky.

Tennessee and Mississippi.—The section of the Mississippi River bordering Tennessee, Arkansas, and Mississippi may be considered as a single unit insofar as the kill of Canada geese using the river bars is concerned. In 1943, it was estimated that not over 50 geese were killed on and in the vicinity of the Tennessee section. It is the belief of W. F. Dearman, formerly director of the Mississippi Department of Fish and Game, that the 1943 bag for his state along the Mississippi River was approximately 800.

Arkansas.—Kills of Canada geese in eastern Arkansas, exclusive of the Mississippi River, are made over such an extensive area and in such relatively small numbers in any given locality that it is difficult to make an accurate appraisal of the over-all loss. In 1943, the bag was about 400, and in 1945 it was probably even lower. After talking with hunters, employees of hunting clubs, and employees of local cold-storage plants, we concluded that the bag of Canada geese in the Stuttgart region in 1945 did not exceed 200.

Louisiana.—In 1943, losses of Canada geese through hunting in the delta and coastal marshes were estimated to be approximately 1,000. Of this number about 150 were estimated to be Mississippi flyway geese; the greater portion of the Canada goose population in Louisiana is in the western portion of the state and probably belongs to the Eastern Prairie population.

Total Annual Bag

Before sound management measures can be instituted for the Mississippi Valley Canada geese, the over-all kill in the population must be known within

fairly close limits. We do not have complete data on the kill, but a reasonably accurate appraisal can be made from available information.

Table 12, summarizing bag data contained in previous discussions, is fairly accurate in some instances and in others represents very rough estimation. It should be remembered that the lowest and highest bags for the various areas represented did not occur in the same calendar year; hence, totals for those respective columns do not represent annual extremes. It would appear from table 12 that the average annual bag in the flyway, 1941–1945, was somewhere in the neighborhood of 19,000 birds.

The annual loss of geese through hunting, expressed as a percentage of the population that left the breeding grounds in the autumn, may be roughly estimated* for the Horseshoe Lake flock and the flyway population as a whole.

The number of geese calculated to escape death from natural causes after leaving the breeding grounds and to be subjected to hunters' guns may be arrived at by adding known hunting losses to inventory figures after the hunting season. For example, the Horseshoe Lake flock numbered about 37,000 geese at the time of the 1943–44 inventory, table 9. Local losses in the Horseshoe Lake area, including crippling, were approximately 16,000 geese, table 9. Assuming that losses between the Canadian border and Horseshoe Lake were average that year, an additional 3,250 geese (2,600, a figure based on band recoveries, plus an assumed 25 per cent crippling rate) were lost.

The autumn kill by the Indians on the breeding grounds is small, fig. 61, as is also the kill by white hunters in southern Canada. Including crippling losses of 25 per cent, the combined kill may be in the neighborhood of 800 birds, about half of which would be contributed by potential Horseshoe Lake geese. Of the 37,000 geese leaving Horseshoe Lake in the spring, approximately 8 per cent are bagged by the natives plus an estimated additional 2 per cent lost through crippling, or a total of 3,700 geese lost. The estimated combined total of all hunting losses for 1943–44 was 23,350.

Inventory figures plus hunting losses for 1943–44 (omitting the spring Indian kill which occurs after the inventory) indicate that the Horseshoe Lake population that left the breeding grounds in the autumn of 1943, and subsequently eluded death from other causes during the following 6 to 8 months' period, was roughly 56,650. Thus, total losses through hunting (including spring losses in Canada) are computed to have been about 41 per cent of the geese that survived death from natural causes. When crippling losses are deducted, it appears that hunters bagged about 30 per cent of the geese that survived death from natural causes.

Over-all loss rates due to hunting for 1944–45 and 1945–46, calculated in a similar manner, were approximately 39 and 40 per cent, respectively, of the population that survived other types of mortality.

Hunting losses for the flyway population as a whole, as might be expected, were at a considerably lower rate than for the Horseshoe Lake flock. In some recent years, the bag of geese in the flyway has been about 19,000, table 12. In some of the same years, inventory figures, table 7, indicate an average population of approximately 60,000. If the bag prior to inventory (roughly 14,600) and the overall crippling, arbitrarily placed at 25 per cent (total 18,250), are added to the approximately 60,000 surviving at inventory, an original population of 78,250 is indicated. Thus, of all flyway geese that survived natural mortality during recent hunting periods, at least 23 per cent are estimated to have succumbed to hunters.

Canada vs. United States Kill

Are the people of Canada, especially the Indians and Eskimos, getting an unjustifiably large share of the Mississippi flyway Canada goose population? Many hunters in the United States would like to believe that such is the case. However, investigators (Soper 1930, Sutton 1932, Brandt 1943, Gillham 1948) of bird life in the far north believe that in most instances the future of waterfowl populations in arctic and subarctic regions is not threatened by the kills made by the native

* Accuracy of the following estimations is in large measure dependent on the accuracy of inventory figures used in the computations.

peoples. It is their belief that the fate of waterfowl populations breeding in the north will be decided by the treatment accorded them on their wintering grounds. We likewise believe that the future of the Mississippi Valley population is dependent on the protection and care it is given south of the breeding range.

On the breeding grounds of the Mississippi Valley Canada geese, there has been a decrease, in recent years, in the number of Indians dependent upon the game resources of the country. After World War I, many of the Fort Albany Indians moved to new trapping grounds far into the interior. According to Dr. T. J. Orford, formerly Indian agent at Moose Factory, in 1945 there were 124 Indians from the Fort Albany band at Lac Seul, a locality to which they had moved in the 1920's. There was another exodus of Fort Albany Indians from the James Bay area in 1942 when 150 transferred to the Constance Lake band on the Canadian National Railway line. Additional Indian families moved down to Moosonee from Fort Albany and Attawapiskat during the years of World War II. As a result of these movements, Indian hunting pressure on wildlife in the James Bay area has decreased. In contrast, the number of hunters shooting Canada geese in the United States, notably in Illinois, has increased tremendously since World War I.

Data in table 12 show that the take in Canada, 1941–1945, was roughly 25 per cent of the total bag of Mississippi Valley geese. When it is remembered that the Indians are partly dependent on geese for survival, that their kill is not a new drain on the goose population, and that in recent years the kill has been found to be proportional to the goose population, this kill cannot be considered excessive.

The relative kill by the Indians and by hunters outside the breeding grounds in Canada and in the United States can be found by comparing the number of geese killed by each group to the total number of birds available to each. It was shown earlier that the Indians kill about 10 per cent or less of the goose population available to them. As the kill in Canada away from the breeding grounds is estimated as not exceeding 1 or 2 per cent of the population, the total Canadian kill is concluded to be 10 to 12 per cent of the population available in any year.

A rough measure of the bag contributed by the flock between the Canadian border and the Horseshoe Lake Game Refuge can be derived from an analysis of band recoveries. Between 1941 and 1944, the number of band recoveries from north of the refuge was equivalent to 33 per cent of the number of recoveries in the region of Horseshoe Lake 1 or more years after banding. The number of geese to terminate their migrations at Horseshoe Lake, 1941–1944, averaged about 45,000. The known bag by licensed clubs in Alexander County in those years averaged 7,780, table 15. Figures based on estimates from band recoveries in 1941–1944 indicate that the flock contributed an average yearly bag of about 2,600 birds before reaching the refuge, or a loss of about 5 to 6 per cent of the numbers that crossed the Canadian border. As the Horseshoe Lake flock in recent years has comprised about 50 per cent of the Mississippi flyway population, the bag of Horseshoe Lake geese (2,600) computed from band recoveries for areas between the Canadian border and the refuge should, if doubled (5,200),* approximately equal the bag of all Mississippi flyway geese in the same area. Calculations from data in table 12 indicate that the estimated mean annual bag for states in the flyway north of Horseshoe Lake (Minnesota, Wisconsin, Michigan, Ohio, Indiana, Illinois,† and Iowa) for 1941–1945 is 5,695, a figure close to the bag figure approximated from band recoveries and from inventory figures and bag data from the Horseshoe Lake area. A check of band-recovery records for the period 1925–1944 shows that most geese bagged in this area were killed in November, fig. 62.

In the fall of 1943, when hunters between the Horseshoe Lake region and the Canadian border bagged between 5 and 6 per cent of the Mississippi flyway geese

* This figure, based on a comparison of band-recovery rates, may be low for two reasons: (1) the percentage of hunters reporting bands they recover is probably lower over most of the flyway than it is at Horseshoe Lake, where the importance of reporting bands has been well publicized, and (2) the geese that spend the greater part of the hunting season north of the refuge are subject to heavier shooting pressure in that region than are the Horseshoe Lake geese in the short time they are there.

† The figure for Illinois (about 1,100) does not include the bag for the Horseshoe Lake area.

available to them, hunters in the region of Horseshoe Lake bagged 23 per cent of the total number of geese attaining the refuge in the fall and winter of 1943–44. Figures for the Horseshoe Lake region, as calculated from data in tables 9 and 15, are 23 per cent for 1943–44, 19 per cent for 1944–45, and 18 per cent for 1945–46.

It is desirable at this point to discuss a type of rumor at times common among waterfowl hunters. During the 1944 hunting season, several hunters at Horseshoe Lake expressed the opinion that, if the ducks and geese needed further protection, the Indians in Canada should be prohibited from gathering and selling duck and goose eggs to a company manufacturing pancake flour. That this kind of complaint is an old story and has no basis in fact was shown by Grinnell (1901).

Various explanations of the change [waterfowl decrease] are given. The blame is laid on the market shooter, on the supposed destruction of birds and eggs on the northern breeding grounds, and on supposed changes in the lines of flight by migrating birds, but most gunners are unwilling to accept the logic of events and to acknowledge that the principal cause of the lessened number of the fowl lies with the gunners themselves, and is an inevitable accompaniment of civilization, not to be changed except by radical measures. . . .

One of the most grotesquely fantastic explanations of the scarcity of wildfowl was put forth several years ago in the newspapers: . . . This story told of an enormous destruction of wildfowl eggs in the Northwest for commercial purposes; millions of shiploads and trainloads of such eggs, it was gravely related, being annually gathered in Alaska and British America, and shipped

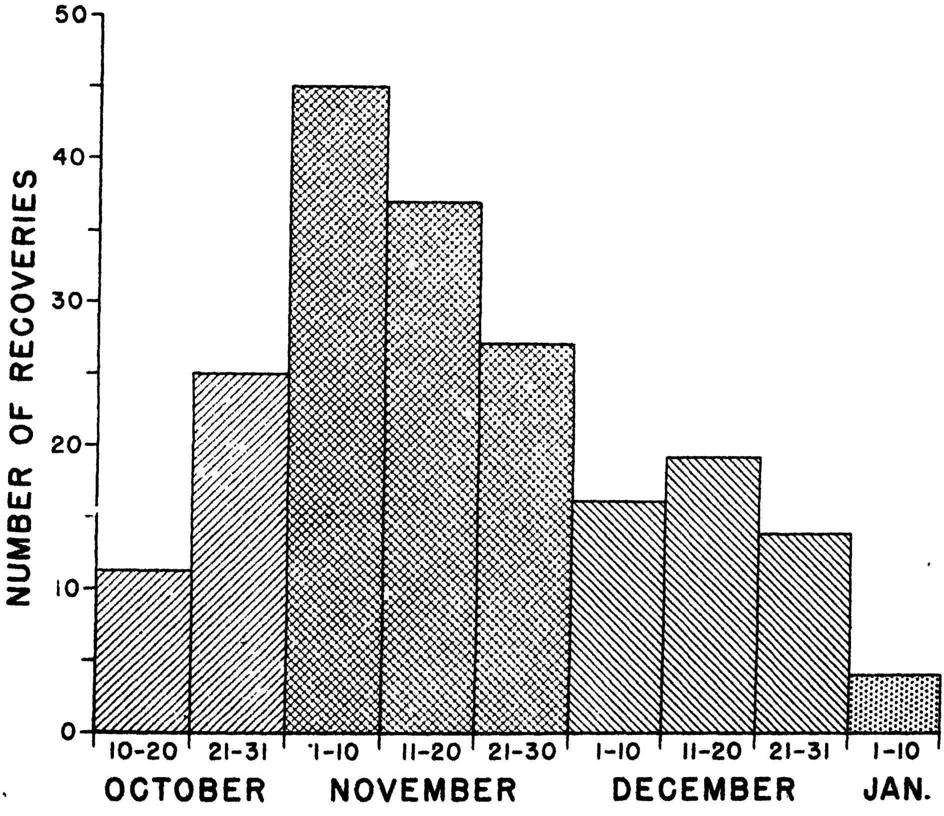

Fig. 62.—Time of kill of Canada geese in Wisconsin, Michigan, and Indiana, as shown by recovery records of Canada geese banded at the Horseshoe Lake Game Refuge and the Jack Miner Bird Sanctuary and recovered in the period 1925–1944. Migration dates and the time of most hunting seasons combined to make November the month of heaviest kill.

thence to points in the East, where they were manufactured into egg albumen cake. . . .

This, then, was the conclusion of the whole matter: Those who professed to have information on the subject were unable to substantiate the stories which they told; the transportation companies have carried no such eggs; none have ever been received at the ports of entry; the albumen trade knows nothing whatever about them, and in view of the total lack of evidence to support the story, there is no doubt that it is a pure invention.

DIFFERENTIAL HUNTING LOSSES

To manage a wildlife species that is subjected each year to heavy gun pressure, it is important to know not only how many individuals of a population are shot annually, but also if the kill in each of the various age and sex groups is proportional to its size in the group, and if the kill places an undue burden on any particular component. One of the causes of concern relative to Canada goose shooting at Horseshoe Lake in recent years has been the disproportionately large kill of juvenile birds, table 23.

What are the underlying factors responsible for a differentially heavier kill of the younger geese? One factor has already been mentioned, namely, the strong bonds existing between members of family units. Related factors are the fearlessness of young geese and their dependence on adults for guidance during their first year of life.

The relationship of juvenile age to unwary behavior in Canada geese was in-

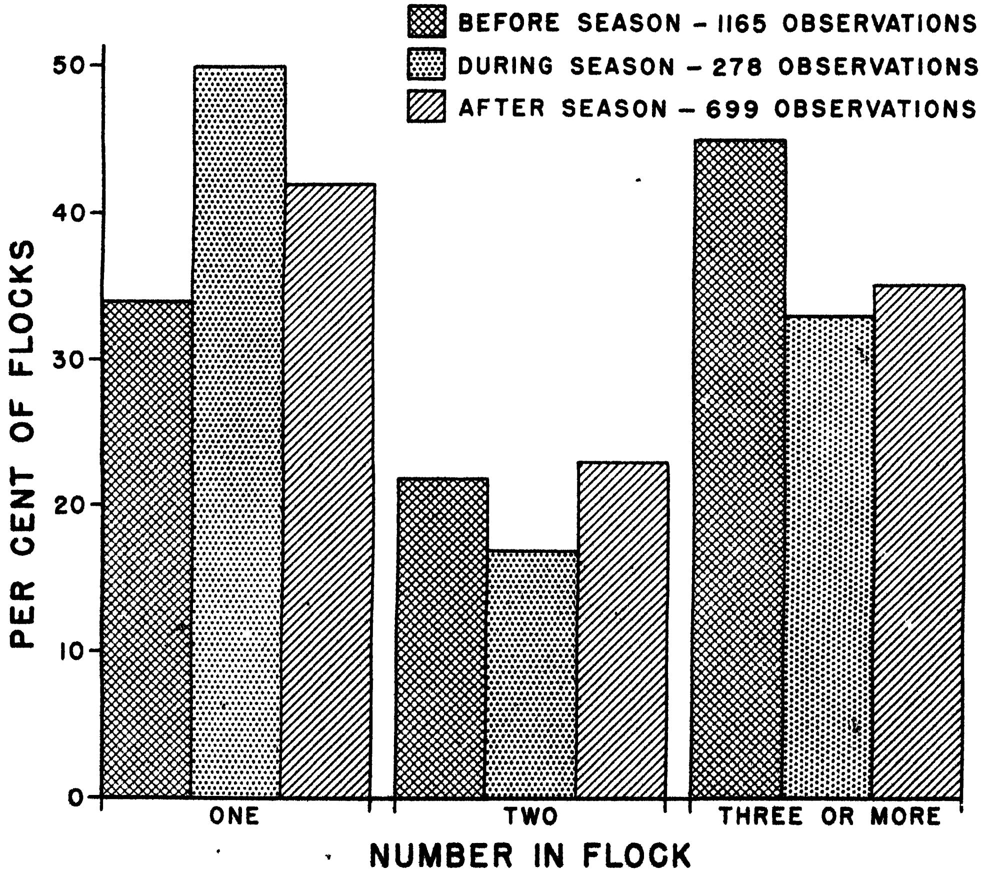

Fig. 63.—Percentages of each of three size-groups (single bird, pair, group of three or more geese) in the total number of flock formations of Canada geese observed before the season, during the season, and after the season at Horseshoe Lake, 1945.

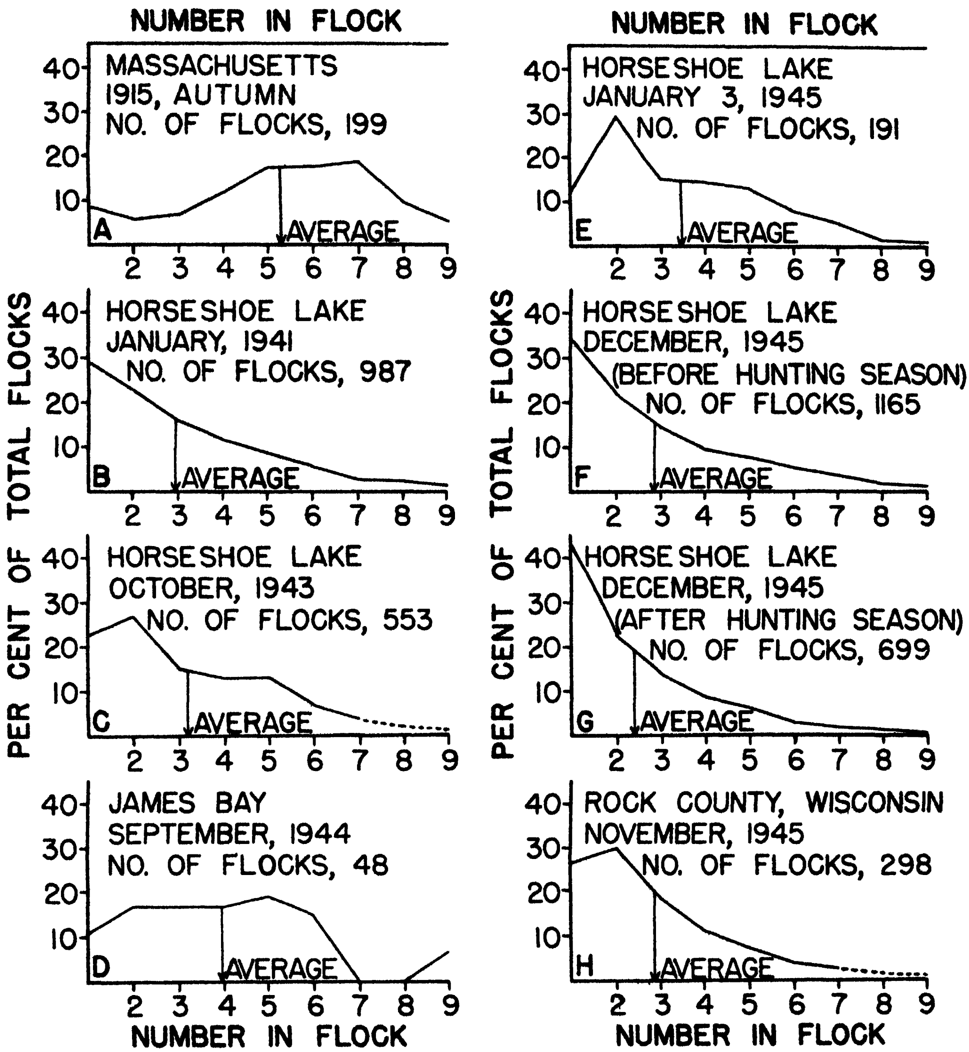

Fig. 64.—Frequency counts of flocks numbering nine or fewer geese and the average size of Canada goose flocks at four different locations.

timated by Phillips (1921). "It was remarked by Massachusetts gunners that there seemed to be a large proportion of young geese, and the same was true of Currituck Sound, N. C., where geese also appeared in unusual numbers and were very tame. The tameness of the geese in Massachusetts this past season caused comment everywhere, and I saw instances of it myself."

At Horseshoe Lake it was found that, as the shooting season progressed, the relative number of single birds increased because of the breaking up of family units, figs. 63 and 64*F*, *G*. Single juvenile birds separated from their families were frequently observed to associate and feed with other family units, as well as with unattached adults, but they were often at the bottom of the peck order, and, as they never appeared to be accepted into the ranks of other families, they often flew alone.

Every veteran goose hunter knows that single birds are "suckers," more readily decoyed than pairs or flocks. During the 1945 season, Arthur S. Hawkins, then with the Natural History Survey, and the

Table 18.—Number of Canada geese shot and size of flock from which they came. Observations at Horseshoe Lake in 1945.

Number in Flock Contributing to Kill	Number Shot From Flocks		Total Individuals Shot	Per Cent of Total Individuals
	One	Two or More		
One....	139	—	139	50 0
Two ..	33	15	48	17.3
Three or more...	75	16	91	32.7
Total..	*247*	*31*	*278*	*100 0*

authors kept a tally of the geese observed killed at several Alexander County shooting clubs and recorded whether they were shot as singles, from pairs or out of flocks. The data gathered, table 18, show that geese shot as singles comprised 50 per cent of the total observed kill. Because single birds were outnumbered by individuals making up pairs and flocks, it is evident that they suffered a disproportionately large share of the kill.

In 1945, when examining bagged geese for sex and age, we asked each hunter whether the bird being checked was shot as a single, from a pair, or from a flock. Because of the two-bird limit, many hunters could easily remember the circumstances under which each of their birds was killed. In some instances we were able to examine geese that we had personally observed shot. The analysis of this portion of the total bag reveals that juvenile geese probably comprised 81 per cent of the number of geese shot as singles, and that approximately 60 per cent of all juveniles bagged were flying alone when shot, table 19.

Table 19.—Age class of Canada geese and size of flocks from which they were shot. Data obtained from hunters at time of bag inspections in Alexander County, 1945.

Number in Flock	Age Class of Geese			Total Individuals
	Juvenile	Yearling	Adult	
One.....	78	6	12	96
Two.....	11	1	4	16
Three or more.	42	6	17	65
Total...	*131*	*13*	*33*	*177*

In most other years for which we have data, the juveniles contributed a disproportionately large share of the total kill, table 23. The extent to which juveniles were more vulnerable to shooting than older geese has been calculated from band-recovery ratios from these two age groups (see page 169). Sufficient data to indicate the approximate difference in vulnerabilities are available for only 1 year. In 1943, the vulnerability ratio in the Horseshoe Lake area was calculated to be 1.0 adult to 8.3 juveniles. Bag inspection data indicate that the ratio continued high in 1944 and 1945, table 23.

Further analysis of our band-recovery data reveals that young geese in their second spring of life, that is, on their return to the breeding grounds as yearlings, continued to be more vulnerable to hunters than the older birds, although the differential was not so great as at Horseshoe Lake. The vulnerability of yearlings compared with that of older geese is based on bandings and recoveries between 1941 and 1944.

The following formula was used to determine the relative vulnerability of yearlings and of older geese on the breeding grounds for the springs of 1942, 1943, and 1944.

$$\text{Vulnerability quotient } V = \frac{\dfrac{\text{Number of recoveries of yearlings from breeding grounds}}{\text{Number of banded yearlings (minus losses at Horseshoe Lake)}}}{\dfrac{\text{Number of recoveries of adults* from breeding grounds}}{\text{Number of banded adults* (minus losses at Horseshoe Lake)}}}$$

By substituting in the formula the appropriate data from our banding files for the years 1942, 1943, and 1944, we have the following equation:

$$V = \frac{\dfrac{75}{2415}}{\dfrac{20}{1804}} = 2.8$$

* Older than yearlings.

Our calculations indicate that the average yearling was about 2.8 times as vulnerable to hunting by the Indians on the breeding grounds as was the average adult (older than 1 year) in the springs of 1942, 1943, and 1944.

Since the bulk of the Indian kill is made from April 15 to June 1, fig. 61, 5 months after the close of hunting in southern Illinois, it would seem that experience gained by the young geese in that interval does not greatly reduce their vulnerability on the breeding grounds. A crucial period that immediately follows their abandonment by the adults results in continued vulnerability of the yearlings to gun pressure.

There is ample evidence that this abandonment occurs just prior to nesting. Unless broken up by shooting, family groups at Horseshoe Lake are often maintained throughout the autumn and winter period. From observations made at his sanctuary, Jack Miner (1923) believed that goose families do not break up until they reach the breeding grounds. This belief is substantiated by the Indians, who have observed that the young of the previous year are separated from the adults shortly before the breeding season. The breeding adults in the captive goose flock at the Bright Land Farm near Barrington, Illinois, according to Charles Kossack of Barrington, are similarly known to drive off their yearling young at nesting time. "Cast off" young geese are on their own, without the guidance of adults, and probably are associated at first in small groups.

One of the reasons for the differential vulnerability of the yearlings on the breeding grounds was suggested in 1946 by John Gunnar and Gilbert Faries, lifelong residents in the James Bay area and experienced goose hunters. They stated that, when the first geese arrive in the spring, many of them are very tame and curious. Gunnar volunteered the opinion that the first arrivals are the nonbreeding geese (yearlings). He recalled that on one occasion, while he was in the Partridge Creek area, a flock of inquisitive Canada geese decoyed within 10 feet of his head, and he expressed the belief that the white garment he wore at the time was responsible for their curious behavior.

Similar lack of wariness in the other species of geese has been noted. Brandt (1943) says of the white-fronted goose at Hooper Bay, Alaska: "And immediately after the lifting of the ice embargo these groups disintegrated into mated pairs, excepting *small* bunches of bachelor males. These free-lance gallants, often in company with like possibly rejected suitors of other species of geese, spend their time moving abstractedly around in inquisitive flocks, *and are ludicrously easy to decoy.*"*

Of the blue goose, Soper (1930) writes: "With the breeding birds resuming, or commencing nesting duties large numbers of nonbreeding geese were left to fly aimlessly about in carefree existence during the brief span of the arctic summer. These were the restless and irresponsible flocks and individuals which from now on were to be observed in the Camp Kungovik locality."

The higher mobility of yearling geese as compared with that of nesting pairs is a factor that may make the young birds readily available to Indians. Nesting adults are known to be extremely wary and secretive, and, unless they are especially sought after, their presence may be known only by chance. Lack of wariness on the part of yearling geese apparently lasts until they begin to band together. In the summer, large flocks, believed to be comprised mainly of yearlings, are extremely wary.

CRIPPLING LOSSES

As crippling losses are a component of hunting mortality, they should be considered a part of the total yearly allowable kill in any game species. Whether a goose ends up on the hunter's table or dies of wounds and furnishes a banquet for some scavenging predator, the net loss to the flock is the same. Reduction of the crippling loss must always be an objective if maximum utilization of a game species is to be achieved.

For many years, waterfowl shooting has been known to produce a considerable loss of unretrieved cripples—a loss that is high

* Italics by the authors of this paper. Boardman Conover, who was in the Hooper Bay area with Brandt, has informed the authors that many flocks exhibiting this kind of behavior were composed of nonbreeding yearlings.

in proportion to the number of birds bagged. In most cases the crippling loss reported for ducks amounts to at least 30 per cent of the number of birds bagged and in some situations one duck is lost for every one bagged (Errington & Bennett 1933, Hawkins & Bellrose 1939, Baumgartner 1942, Hochbaum 1944). In Michigan about 10 per cent of 105 ducks trapped and examined carried shot (Whitlock & Miller 1947), but what percentage of these ducks died later as a result of the prolonged effect of carrying shot is not known. Recent fluoroscopic studies made by the Illinois Natural History Survey of ducks trapped at Spring Lake on the Mississippi River and at Lake Chautauqua on the Illinois River revealed that approximately 25 per cent of the mallards migrating through these areas carry lead shot in their bodies as a result of shooting.

Goose shooting at Horseshoe Lake, 1940–1945, resulted in crippling losses similar to those reported to occur in duck hunting. To anyone who observed the shooting at clubs bordering the refuge at Horseshoe Lake in the years of this study, it was apparent that the height at which a goose flew over the hunters seldom determined whether it was shot at. The situation was aggravated by the heavy concentration of hunters; hunters in the first line of pits or blinds attempted to "reach" approaching geese before the birds flew over the next line of pits. Novice goose hunters usually underestimated distances, while expert shooters, disgusted with the ease with which geese leaving the refuge could be killed, sometimes found sport in attempting to "scratch down" the high birds.

High shooting, some observers believed, saved large numbers of geese by frightening them off before they could fly within killing range. This was undoubtedly true during the early part of a season when the geese were not working out of the refuge in great numbers, or in years when low kills were made, but late in a season when geese were so numerous in flight over club grounds that the majority of hunters, even those who indulged in high shooting, got their limits, or in a year of high kill rate when the season was limited by a predetermined kill, high or indiscriminate shooting was a factor certain to cause needless crippling and increase the total loss.

In 1944, a questionnaire was circulated among goose hunters to obtain their own appraisal of their shooting. During the 21-day season, 103 hunters were asked questions about the following items: number of shells fired, estimate of geese lightly hit, number of geese severely crippled and not retrievable, and the number of geese bagged. An analysis of the accumulated data shows that the average bag per hunter-day was 1.69 geese. Since the average hunter success for all clubs in the vicinity for the entire season was 1.44 geese per hunter-day, it can be assumed that a fairly representative group of hunters was sampled.

The 103 hunters reporting estimated that with 1,374 shells they had bagged 286 geese and had severely crippled 51 geese; the number of geese crippled was equivalent to 18 per cent of the number bagged. This percentage probably represents the minimum crippling loss. The hunters reported that they had lightly hit an additional 176 birds, or a number equivalent to 61 per cent of the number bagged. Thus, according to their own estimates made the day of hunting or a day after, these hunters hit, with varying degrees of severity, and did not recover, a number of geese equaling 79 per cent of the number that they recovered. However, this figure is so high as to cast some doubt on its validity.

In 1945, Arthur S. Hawkins, then of the Illinois Natural History Survey, and the authors observed the shooting at several clubs and made on-the-spot tallies of the number of geese bagged and the number crippled but not recovered. The tally of crippled birds included only those that had been obviously and severely hit, but others may have suffered mortal body wounds without exhibiting a noticeable reaction to their wounds at the time of being shot. The hunters under observation bagged 253 geese but failed to recover an additional 62 badly crippled birds, most of them able to fly well enough to regain the lake within the refuge boundary, but so severely crippled as to be unable to survive the winter. Thus, in addition to each four geese bagged, ap-

proximately one additional goose died as a result of shooting—a minimum crippling loss of 25 per cent. At a few clubs the ratio of birds crippled to birds bagged frequently exceeded a ratio of one to one. Two instances of extreme crippling were observed: in one, four geese were crippled and none bagged, and, in the other, seven were crippled and six bagged.

From the various data presented above, we conclude that a conservative figure for the over-all loss owing to crippling at Horseshoe Lake is at least 30 per cent of the total bag. Crippling data are lacking from other areas in the flyway, but it is doubtful if the rate attained at Horseshoe Lake was exceeded. Where shooters are widely spaced and are not competing with each other to knock down the same high-flying birds, there is relatively less wild firing and hence less crippling.

Since crippling is more or less directly related to the number of shells fired, information was sought on the number of shells the average hunter expended to secure one goose. The hunters canvassed by questionnaire in 1944 reported that they fired an average of 4.8 shells per goose bagged.

In 1945, data of a similar nature were obtained by an examination of shooting pits at the end of the first day of hunting. Of the 42 pits examined at two club shooting grounds bordering on Horseshoe lake, the average pit contained 37 recently fired shell casings. As each of the hunters at these clubs killed his limit of two geese, and as no more than two hunters were permitted in each pit, the average number of shells fired to kill one goose on opening day in 1945 was nine.

How does this score at Horseshoe Lake, where goose shooting was relatively easy, compare with goose-shooting scores elsewhere? On the basis of his goose-hunting experiences in the West, Major Askins (1945), a noted authority on arms, believes that one goose to three shells, when distances are less than 80 yards, is about the best score an average hunter can expect. Most of his shooting was of the pass variety, and he states that it is doubtful if his score was better than one bird in four shots.

Geese wounded near Horseshoe Lake generally attempted to regain the lake either by flying or by eluding the hunter on the ground. Since hunters were not permitted to recover cripples that entered the refuge, club owners, at the opening of the 1943 season, were required to erect a 2-foot woven-wire fence between the pits and the lake to aid hunters in retrieving wounded geese that had been knocked down in the fields. Through this device, hunters secured a fair number of birds that would otherwise not have been recovered.

Crippled geese within the refuge were usually found apart from the flying birds, sometimes gathering in flocks of 10 or more. The strongest cripples swam about in the lake, where they sought shelter close to shore among the cypresses and snags, fig. 42, but the weaker ones rested on the lake shore. Few badly shot geese recovered from their wounds; many survived for a time, but in their weakened condition they became victims of predators. Raccoons consumed many dead geese (Yeager & Elder 1945). Although unable to catch healthy birds, these animals apparently sought out and killed many of the cripples, the remains of which were usually found along the shore line or on logs some distance from shore. A few carcasses were pulled under water and eaten by turtles. Skeletons of many geese have been observed on the lake bottom in years when cripple surveys have been made on ice. Undetermined numbers of geese sought shelter and died in parts of the lake that were inaccessible to man because of the large number of dead trees and fallen logs. Some cripples were caught by foxes and dragged into the woods on the refuge, where they were devoured; others died on hunting lands away from the lake. Consequently, a count of skeletons and carcasses around the shore line and on the island and club grounds represented only a portion of the total loss.

To determine at least the minimum number of unretrieved geese that died of wounds, counts were made of goose carcasses along both island and outer shore lines of the lake, as well as on the grounds of the principal goose clubs. The total counts of carcasses each winter, from 1940–41 through 1945–46, are given in table 20. Not all carcasses counted, of course, represented cripples that had died,

Table 20.—Number of carcasses of Canada geese counted on and near the Horseshoe Lake Game Refuge, 1940–41 through 1945–46.

Season	Total Carcasses Counted	Geese Found Dead per 100 Bagged at Licensed Clubs Around Refuge	Inclusive Dates of Counts
1940–41	466	3 61	January 19–20
1941–42	—	—	—
1942–43	421*	6 70	October 20–December 20
1943–44	1,048	9 39	December 17–28
1944–45	555	7 75	November 24–February 8
1945–46	648	14 58	December 6–31

* Estimated by W. H. Elder, then of the Illinois Natural History Survey, from counts on 10 sample quarter-mile strips of refuge shore line.

as some deaths were due to lead poisoning and disease. Data for the several years in table 20 are not directly comparable because the amount of outer shore line and the number of clubs surveyed for cripples varied annually. In general, coverage was increasingly extensive and thorough in successive years.

The legs and feet of the crippled geese, which seemed to be choice items of food to predatory animals, either were eaten where the birds were found or were carried off. A tally of 391 carcasses in 1945, a little over a month after the close of shooting, showed that only 21 per cent still retained both legs and that 5 per cent had but one leg. Many of these carcasses were fresh or only partially eaten when counted, and the number of legs eventually consumed by predators during the winter was estimated to be nearly 100 per cent. Because of the scarcity of legs, few carcasses yielded bands, a tally of which, when compared with the known kill and band recovery from hunters, would have permitted a fairly accurate appraisal of the crippling loss.

An analysis of our data on unretrieved cripples that later died indicates that adults succumb less quickly after being wounded than do juveniles. A week after the close of the 1944 season, during which 9.4 juveniles were bagged for every adult, the ratio of juveniles to adults found dead along the shore line of one club adjoining the refuge was 32:1. A month after the close of the season the ratio was down to 1.5:1.0. In a similar count a week after the close of the 1945 season, during which 4.1 juveniles were bagged per adult, the ratio of juveniles found dead to adults found dead was approximately 3:1.

MISCELLANEOUS MORTALITY FACTORS

Although no attempt was made to investigate all causes of death in the Canada goose population of the Mississippi valley flyway, a few mortality factors, in addition to shooting, were studied.

Lead Poisoning

Lead poisoning in Canada geese has been recorded from widely separated parts of the country: near Galveston, Texas; Currituck Sound, North Carolina (Grinnell 1901); Barry County, Michigan (Pirnie 1935); St. Clair Flats, St. Clair County, Michigan (Howard 1934); and Columbia County, Wisconsin (Adler 1944).

Because Canada geese are chiefly grazers, they are less apt to ingest lead shot than are ducks, which secure much of their food off the lake bottoms by straining great quantities of mud through their bills to extract seeds. Among geese at Horseshoe Lake, deaths resulting from lead poisoning were most frequently observed in late winter and early spring during the period of study. Mainly responsible for this seasonal mortality from lead was, of course, the great abundance of lead shot available toward the close of the hunting season on the surface of cultivated fields over which shooting had been heavy. Diminishing food supplies as the season

advanced increased the likelihood that geese would pick up shot in fields planted to winter wheat, one of their principal foods in the Horseshoe Lake area. In areas where the ground held much moisture and the wheat plant was devoured down to the roots, some soil and probably any shot that happened to be present were ingested. Geese at the refuge were observed to devour considerable quantities of soil at times, particularly in winter. In certain farmed feeding areas, holes as much as 6 or more inches deep and several times as wide were created by the geese in their ostensible search for food. This type of feeding increased the likelihood of the birds occasionally swallowing lead shot.

"Tip-up" feeding by Canada geese in the water of the Horseshoe Lake area was observed in late winter. This habit may have been a response to a reduced food supply on land. In 1942, a slough on the west side of the lake was a favored "tip-up" ground. Dr. William H. Elder, while with the Illinois Natural History Survey, when surveying this area for cripples, found 13 dead or dying geese on the ice or close to the shore line. Of 23 geese autopsied by Dr. Elder in late winter, 20 were found to have died of lead poisoning, 18 of these containing shot in their gizzards.

Paul S. Smith of the United States Fish and Wildlife Service, who conducted a series of tests on one of the most heavily shot club grounds, found about one lead shot per square foot of top soil, 1 inch in depth. Only the fact that the grounds of hunting clubs were cultivated each year prevented losses due to lead poisoning from assuming greater proportions. The potential danger from lead shot increased each year of the study, and the proximity of heavily shot fields to such an important concentration area as the Horseshoe Lake Game Refuge constituted a significant hazard to the geese wintering there.

Starvation

A Canadian Indian whose hunting grounds lie in the Lawapiskau River* country related that during late springs, when snow remained on the ground for some time after the arrival of Canada geese, he found dead birds that were in a very emaciated state, a condition that he attributed to a lack of available food. Because it is likely that, as a result of disease, lead poisoning, or crippling, a few geese succumb soon after their arrival on the breeding grounds, it is impossible to assess from this single report the importance of starvation as a cause of death in Canada geese. Nevertheless, there is some evidence that a food shortage in late spring may result in death of the weakest birds. In the second week of May, 1947, when the rivers and creeks were frozen and the country was still under several feet of snow, geese shot by Indians at the south end of James Bay were reported as having only willow catkins in their gizzards.

* This river flows into James Bay 20 miles south of the Albany River.

Bound Crop

Occasionally Canada geese were found in the vicinity of Horseshoe Lake in a thin, weakened state and with greatly

Fig. 65.—Esophagus, proventriculus, and gizzard of a Canada goose found dead on the Bright Land Farm near Barrington, Illinois. Death in this case was due to lead poisoning from 38 shot found in gizzard. Food impaction is the result of lead poisoning, which often causes paralysis of the digestive tract in Canada geese and other waterfowl. (Photograph by Charles W. Kossack.)

distended crops. Examination of these individuals revealed that an impacted crop was often the primary cause of their condition, and, though operative measures were tried, few of these geese had sufficient stamina left to survive. Their crop contents usually consisted of a tightly packed mixture of wheat browse, corn,

and cowpeas, or soybeans, and frequently leaves and portions of the stems of the two legumes. In some of these, bound crop may not have been the direct cause of loss of weight and strength; instead it may have been the result of partial paralysis and weakness resulting from lead poisoning, fig. 65.

C. E. Laughery, formerly refuge manager at the Horseshoe Lake Game Refuge, informed us that geese with bound crops were most frequently found in years when a considerable acreage on the refuge was planted to cowpeas. Cowpea fields attract large numbers of geese long after the bulk of the crop has been consumed. A few geese, while searching for peas, evidently consume fibrous and relatively indigestible portions of the plant. The presence of such material in the crops of geese may be responsible for impactions.

In recent years, soybeans were planted extensively in southern Illinois, and the geese tended to utilize this crop to a greater extent each year. There was frequently much wastage in harvesting these beans; many fields in the vicinity of Horseshoe Lake were not combined until an appreciable portion of the crop had been lost through shattering. As a result, beans in abundance were available to geese for several weeks after most of the local corn crop had been utilized or removed from the fields, fig. 66. While consumption by geese of shattered and otherwise wasted soybeans may seem desirable, these beans may sometimes have contributed to a number of deaths resulting from bound crop.

In the winter of 1943–44 in particular, Paul S. Smith, when surveying the vicinity of the refuge, found a number of dead geese, their crops tightly packed with soybeans. These birds were said to differ from the crop-bound birds described above in that they were particularly heavy and fat. Probably in the winter certain geese fed more extensively on soybeans than on other foods and, as soybeans have a high protein and fat content, these individuals became heavier than the average goose of the area. Apparently these geese died after drinking water when their crops were crammed with beans. The pressure resulting when the beans imbibed water and swelled may have been the direct cause of death in such cases; the mechanism of the lethal effect is not known to us.

Fig. 66.—Canada geese in a harvested soybean field near Horseshoe Lake, autumn 1946.

Geese frequently stuff their crops tight with corn, but in only one instance was corn suspected of being an indirect cause of death. This individual with an overloaded crop, fig. 67, became agitated in

Fig. 67.—The Canada goose is a voracious eater. This individual with an overloaded crop became frightened when a game technician entered the trap in which it had been caught. It had extreme difficulty in breathing and died a few minutes later.

the trap and died shortly thereafter, exhibiting the syndrome typical of anoxia.

Rough tests of the swelling properties of dry soybeans and corn revealed that the beans present a much greater hazard as food for geese than does the corn. Soybeans and corn were soaked in water for intervals varying from 30 minutes to 6 hours. Water displacement measurements showed that the soybeans increased their bulk at a rate approximately three times the rate corn increased its bulk. At the end of 3 hours, soybeans had increased their bulk by 85 per cent and corn by 30 per cent. These data and field observations suggest that soybeans and cowpeas may not be ideal crops to plant for the express purpose of providing food for wintering concentrations of Canada geese.

Predators

The red fox is probably the only predator at Horseshoe Lake that is capable of catching sound, healthy geese. Remains of geese found in cornfields late in the autumn point to predation by foxes, but probably most carcasses represented secondary predation involving birds crippled during the hunting season.

In each year covered by this study, a pair of bald eagles nested on the island in Horseshoe Lake, and both adults and juveniles were observed regularly throughout the autumn and winter periods. In the autumn of 1945, the eagle population on the refuge numbered at least five. Eagles were frequently seen feeding on crippled geese that had died, and in December, 1945, several eagles were observed by Paul S. Smith to attack a live goose (probably a weak cripple) that was frozen to the ice by its feet and breast feathers. Eagles were never seen to attack a sound, healthy goose.

Bald eagles are reported to feed on wounded geese in the Port Joli area of Nova Scotia, and never to be absent from the area as long as the geese remain (Tufts 1932). A discussion of predators on the breeding grounds will be found in the section on "Productivity."

Diseases

Only two diseases were investigated at Horseshoe Lake: tracheitis and aspergillosis.

Tracheitis.—In January, 1945, a number of geese trapped were found to have wheezy voices, indicative of a congested tracheal condition. Two of these birds eventually died, and the lungs and trachea of one were sent to the Department of Animal Pathology and Hygiene, University of Illinois, for examination. The cause of death was diagnosed as tracheitis, pulmonary congestion, and edema.

The symptoms of the disease as observed at Horseshoe Lake were a voice pitched higher than normal, a distinct "wheeze," and heavy, spasmodic breathing, accompanied by a forward throw of the head and open mandibles as the bird gasped for air, fig. 68. As the disease progressed, the effort attendant upon the intake of

Fig. 68.—Canada goose near death from tracheitis. Symptoms of this disease are a forward throw of the head and neck and gaping as the bird gasps for air.

air became increasingly spasmodic and violent because of the whitish exudate that accumulated in the trachea at the junction of the bronchi.

Both field experience and laboratory findings indicate that tracheitis is infectious, but the nature of the infectious agent is uncertain. Graham & Thorp (1931) have reported that a Canada goose from a farm flock had clinical symptoms analogous to acute laryngotracheitis in domestic fowl. However, autopsy of the goose revealed that the lung contained foci of mycotic pneumonia.

Aspergillosis.—The manifestations of aspergillosis in waterfowl have been adequately described by Phillips & Lincoln (1930). While outbreaks are known to occur occasionally in duck populations (Phillips & Lincoln 1930; Pirnie 1935; Bellrose, Hanson, & Beamer 1945), only one instance of its occurrence in Canada geese in the wild has been recorded previously (Dow 1943).

At Horseshoe Lake on November 7, 1946, a juvenile Canada goose was found in a much weakened condition. Within a day it was dead, and autopsy revealed that the typical nodules associated with *Aspergillus* infections were present throughout the body cavity, fig. 69, left. In December 1946, a second juvenile goose was found dead from an *Aspergillus* infection. Postmortem examination of this specimen by the Department of Animal Pathology and Hygiene revealed that the air sacs were partly, or in some cases completely, filled with a fungus growth, fig. 69, right, that upon cultural examination presented the characteristics of *Aspergillus fumigatus*.

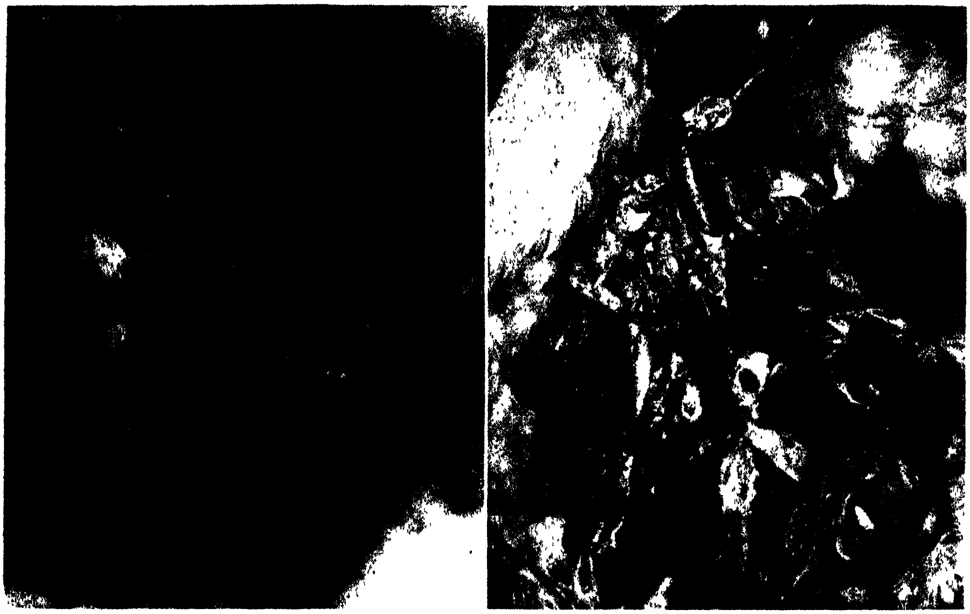

Fig. 69.—Aspergillosis in Canada geese. The nodules of *Aspergillus* infection shown in the illustration at left are on the lateral wall of the body cavity. In the goose shown in the illustration at right, the air sacs are the principal foci of infection. Both specimens were juveniles.

Parasites

Both internal and external parasites were taken from Canada geese wintering at Horseshoe Lake.

External Parasites.—Four species belonging to four different genera of chewing lice or Mallophaga were taken from Canada geese at Horseshoe Lake. Specimens of *Trinoton querquedulae* Linnaeus collected in the winter of 1945–46 were identified by Dr. Carl O. Mohr, then of the Illinois Natural History Survey staff. The following species, collected from a dead goose in 1934, were identified by R. O. N. Malcomson: *Anatoecus*

ferrugineus Giebel, *Esthiopterum crassicorne* (Scopoli), and *Ornithobius goniopleurus* Denny.

Internal Parasites.—Flukes were frequently encountered in the cloacae of Canada geese at Horseshoe Lake when examinations were made for sex and age. A number collected in the winter of 1945–46 were referred to Dr. L. J. Thomas of the Department of Zoology, University of Illinois, for identification. In his report he identified these specimens as *Echinostoma revolutum* and *Prosthogonimus* sp.; specific identification in the latter genus was impossible because of the poor condition of the specimen.

PRODUCTIVITY

It is important to know several months in advance the probable population of any game species at the start of a hunting season in order to determine what hunting restrictions will be necessary in that season. Populations of nonmigratory game can be estimated or inventoried before the hunting season more easily than can those of such migratory species as the Canada goose, which nests in comparatively inaccessible regions. Because of the length of time generally required before they can be officially approved, hunting regulations for migratory waterfowl must be decided upon while the actual size of the fall population is still an unknown. Thus, it is desirable to be able to forecast the population accurately from data obtained during the previous season. Forecasts can be made more easily for a population of limited size and distribution, such as the Horseshoe Lake goose flock, than for immense, continent-wide populations.

To interpret and predict population trends from flocks on their wintering areas, such questions as these must be answered: What is the age ratio, within the flock, of juveniles to adults? What are the survival rates of various age and sex groups? How long do geese live? How many or what percentage of a population attain breeding age? What is the ratio of males to females? Does a disproportionate kill occur in the various sex and age groups? Answers to these questions have been sought in studies of the Canada goose at Horseshoe Lake and on the breeding grounds, and in records of geese banded at the Miner Sanctuary.

Breeding Potential

The theoretical capacity of a species to produce young is determined by mating habits, age at reproductive maturity, ratio of males to females, and number of young produced per season. Information in the literature on these subjects is briefly summarized to aid in interpreting the significance of related data from the Mississippi flyway.

Mating Habits.—The Canada goose is monogamous and, judged from the habits of captives, fig. 70, remains paired to the same mate as long as both are alive. In captivity, individuals have been known to re-pair after the death of a mate (Montgomery 1938), although in some cases several years may elapse before remating takes place (Miner 1923). Remating experiments with Canada geese by Charles Kossack and Carleton Beckhart at the Bright Land Farm near Barrington, Illinois, have shown that a very high percentage of captives will remate the first spring following separation from their mates.

Reproductive Maturity.—At least 2 years are required for the Canada goose to reach sexual maturity in the wild, and in captivity the age of maturity is often 3 years and sometimes 4 (Dutcher 1885, Bailey 1913, Taverner 1922, Wilfrid 1924, and Forbush 1925). Studies made by the Illinois Natural History Survey of the semicaptive flock at the Bright Land Farm revealed that 25 per cent of the geese bred during their third year (Elder 1946).

Definite information on Canada geese breeding in the wild at 2 years of age is lacking. If the presence of an open oviduct is a sign of sexual maturity or an indication that eggs have been produced, data from Horseshoe Lake indicate that in the wild practically all females are productive at 2 years of age. However, until further information is available, inclusion of all wild geese in their third year of life in the breeding component of the population must be considered tentative. Of 54 females banded as juveniles and retrapped and examined at Horseshoe Lake in their

Fig. 70.—Female Canada goose and newly hatched young on the Bright Land Farm near Barrington, Illinois. (Photograph by Charles W. Kossack.)

second winter, all possessed closed oviducts (at about 1½ years of age); but of 18 females retrapped and examined in their third winter (at about 2½ years old), all but one possessed open oviducts (Hanson 1949*a*).

The duration of fertility is probably not a factor limiting the productivity of Canada goose populations, as captives have been known to raise young at ages that far exceed the length of life of most individuals in the wild, few of which live longer than about 5 years (see section on "Population Survival").

Sex Ratios.—Sex ratios of Canada geese as they were obtained from trapping and from bag inspection in the vicinity of Horseshoe Lake are given in tables 21 and 22. In the juvenile age class, trap data for the period of study indicate a slight but statistically significant excess of males; bag data, on the other hand, indicate no

Table 21.—Number of male and female juvenile Canada geese newly trapped and banded and number examined in bag at or near Horseshoe Lake, 1940–41 through 1946–47.

Season	Geese Banded			Geese Inspected in Bag		
	Total Number Banded and Sexed	Number Females	Per Cent Females	Total Number Inspected	Number Females	Per Cent Females
1940–41	143	68	47.6	213	110	51 6
1941–42	272	128	47.1	50	37	74 0
1942–43	619	284	45 9	549	254	46.3
1943–44	1,379	634	46.0	354	140	39 5
1944–45	607	272	44.8	379	184	48 5
1945–46	196	106	54 1	689	341	49 5
1946–47	296	102	34.5	—	—	—
Total	*3,512*	*1,594*	—	*2,234*	*1,066*	—
Average			45 4			47.7

significant variation from a 1:1 ratio. In the adult age class, according to trap data, there is a significant preponderance of males, but bag data fail to show a significant deviation from a balanced sex ratio.

Which of the ratios for the adults in table 22 more nearly represents the actual sex ratio for that age class in the population? Trap ratios might be more nearly correct because observations of banded birds (banded on left or right foot according to sex) feeding around the traps have revealed no greater wariness on the part of either sex. On the other hand, a preponderance of males would not be surprising, as a disproportionate loss of females could be expected to occur during the breeding cycle. The validity of the adult bag ratio as a representation of the actual sex ratio in the adult group is questionable because it indicates that the ratio of the sexes in this older age group is more evenly balanced than the ratios for the juveniles found from either trapping or bag inspection. The actual sex ratio in the adult population may lie somewhere between the two figures given in table 22.

Number of Young.—Five eggs represent about the average clutch size of the Canada goose in the wild, according to other observers. At Honey Lake, California (Dow 1943), 169 nests examined in 1939 contained an average of 5.09 eggs per nest, and 249 nests examined in 1940 contained an average of 5.10 eggs. A study of goose nesting at the Bear River marshes of Utah revealed an average of 4.88 eggs per clutch for 84 nests (Williams & Nelson 1943).

Table 22.—Number of male and female adult Canada geese newly trapped and banded and number examined in bag at or near Horseshoe Lake, 1940–41 through 1946–47.

Season	Geese Banded			Geese Inspected in Bag		
	Total Number Banded	Number Females	Per Cent Females	Total Number Inspected	Number Females	Per Cent Females
1940–41	170	81	47 6	55	22	40.0
1941–42	124	47	37.9	29	11	37.9
1942–43	404	187	46 3	212	104	49.1
1943–44	950	416	43.8	90	50	55.6
1944–45	246	82	33.3	40	20	50.0
1945–46	114	49	43.0	168	84	50.0
1946–47	205	67	32 7	—	—	—
Total	*2,213*	*929*	—	*594*	*291*	—
Average			41 9			48.9

The number of eggs produced by captives is surprisingly close to the production attained by wild birds. In 1942, 54 pairs of Canada geese on the Bright Land Farm produced 260 eggs, or an average of 4.81 eggs per pair. Several people experienced in raising Canada geese have stated that the number of eggs laid may vary with the age of the birds. Dutcher (1885) cites a game breeder on Long Island who claimed that 4 eggs are laid the first year of breeding, 5 the second, and 6 or 7 thereafter. Miner (1923) also states that "a young goose will lay four eggs the first year [of laying] and usually five the second."

Actual Productivity

The number of young birds brought to the flying stage is always somewhat less than the theoretical maximum. Fertility of Canada goose eggs is evidently high. In California and Utah, an egg fertility of 93 and 94 per cent, respectively, was found. However, flooding, predators, and other agents may destroy as high as 40 to 48 per cent of the nests in California (Dow 1943) and thus reduce production of young. Consequently, the annual production for all pairs that nest may average only 2.48 to 2.84 goslings per pair, or about 50 per cent of the number of eggs produced. In Utah, 84 nests studied yielded an average of 3.9 goslings per nest (Williams & Marshall 1938). Second nestings are sometimes attempted, a factor that would somewhat increase the average annual productivity per pair.

Information volunteered by the Indians at Moose Factory, Fort Albany, and Attawapiskat suggests that the red fox is the predator most destructive to Canada goose nests in the James Bay area. The extent to which foxes are harmful to goose nests is probably inversely related to the population levels of other prey species. In 1946, a year during which foxes were abundant, but snowshoe hares, muskrats, grouse, and ptarmigan were low in numbers, Indians reported finding many Canada goose nests destroyed by foxes. When interviewed in the summer of 1947, one Indian said, "The foxes are now low in numbers. Let's wait and see what kind of luck the geese have in raising young this year."

These attitudes by a native people, who are the keenest of observers, should be given careful consideration. Recent studies have generally confirmed the belief that predators have little effect in controlling the numbers of cyclic prey species, but in the case of Canada geese we are dealing with a bird that is normally of secondary importance as a prey species and that at present is not known to be cyclic. If geese and other waterfowl are subject to increased predation by foxes when these animals are at the peak of their cycle, it is conceivable that the numbers of waterfowl could be measurably affected by fox predation.

A few Indians that remain in the interior occasionally take goose eggs, but as the greater number of the Indians are at the coastal posts, fig. 55, during the nesting season, the importance of Indian predation is negligible.

Juvenile mortality in Canada geese appears to be small. In Utah a 3 per cent decrease in average brood size occurs over a period of a month (Williams & Marshall 1938). Little is known concerning predation on broods, but in one recorded instance in British Columbia ring-billed gulls devoured a brood of newly hatched goslings (Munro 1936).

The scarcity of natural enemies in the James Bay muskeg area normally insures small losses of goslings to predators; coyotes are absent, wolves almost nonexistent; lynxes, minks, martens, fishers, and otters are generally scarce, and wolverines are extremely rare. Probably foxes, abundant at the peak of their cycles, are predators of consequence only in years in which populations of snowshoe hares and other prey species are low. Great horned owls are fairly common and may account for the loss of a few young geese.

Data From Horseshoe Lake

The degree to which goose productivity measurements at Horseshoe Lake are a valid measure of the actual productivity of the Horseshoe Lake flock on the breeding grounds is dependent upon the magnitude of the losses between the James Bay area and Horseshoe Lake (see section on "Annual Bag").

The autumn kill by the Canadian Indians is small, fig. 61, so that, even if more

Fig. 71.—Type of trap used to catch Canada geese at Horseshoe Lake. Trap consists of eight wood and wire frames roofed over with twine netting and supported with guy wires. Open ends are closed off by tripping a pipe-weighted, twine curtain from a blind.

young than adults are killed in proportion to their numbers, the ratio of juveniles to adults in the flocks is not changed appreciably by the time the geese migrate southward. The scarcity of band recoveries between James Bay and southern Canada further indicates that the flocks are still largely intact when they reach the northern border of the United States. From fig. 38 it is evident that the majority of the geese have arrived at the Horseshoe Lake Refuge by November 1. As the bulk of the kills north of the refuge are made after this date, fig. 62, most of the flocks that arrive at the refuge have been only moderately depleted by shooting; band recoveries indicate that total hunting losses between the Canadian border and Horseshoe Lake are usually 5 to 6 per cent of the southward bound population. Because of the small migration losses in the population, the over-all ratio of young

Fig. 72.—Canada geese feeding into drop curtain trap at Horseshoe Lake.

to old in the flocks as they arrive in southern Illinois probably does not differ greatly from ratios existing at the time the family groups start their southward migrations; therefore, we believe that age and sex ratios at Horseshoe Lake furnish reasonably accurate measures of actual productivity ratios in most years.

Trapping data and data from bag inspection and band recoveries combined have been used in measuring production of the Canada geese wintering at Horseshoe Lake.

The age ratios of the geese caught in traps are believed to be fairly representative of the untrappd population for the following reason: No significant difference was observed in the wariness of geese of the various age classes as the birds entered the traps (many geese were color-banded to indicate age classes). Many catches consisted of individuals that had entered the traps, fig. 71, as parts of a busily feeding wedge; such catches would not represent selective trapping, fig. 72.

The ratio of juveniles to adults during the early part of the autumn no doubt differs to some extent from the ratio after the hunting season because of the proportionately greater kill of juveniles, table 23, but we are not able to demonstrate the extent of this difference from the data at hand.

The total annual catch since the winter of 1943–44, excluding repeats, includes a large percentage (5.4, 22.5, 42.7, and 30.0 per cent, table 1) of geese trapped and banded in previous years (trap returns), many of which are accompanied by their unbanded young. Therefore, the ratio of juveniles to adults among the newly banded birds, table 23, is not indicative of the age ratios in the flock as a whole, as it necessarily excludes the many banded adults that returned to the traps.

The ratio of juveniles to adults for entire-season catches is given in table 24. The figures for the season catches in this instance include the geese trapped in a specified season but banded in a previous season (trap returns) as well as the newly banded birds, but they exclude birds banded and retrapped in the same season (repeats). These data more nearly represent the actual juvenile-adult ratio in the flock than do the data on newly banded geese given in table 23.

Data from bag inspection are indicative of true flock ratios only when they are corrected for differential hunting vulnerability of the juveniles by means of trap and band-recovery data. Age ratios derived directly from band-recovery data do not accurately reflect the age ratios in the total population for the same reason that the age ratios of unbanded geese in the hunters' bag do not, namely, that the banded juveniles are shot more heavily in proportion to their actual numbers than are the banded adults. However, age ratios derived from band recoveries can be used to correct bag ratios for the disproportionate kill of juveniles as follows: (1) Determine the relative vulnerability to shooting of the juveniles and the adults. (2) Use the vulnerability quotient of the

Table 23.—Number of juvenile and adult Canada geese newly trapped and banded and number examined in bag at or near Horseshoe Lake, 1940–41 through 1946–47.

Season	Geese Banded			Geese Inspected in Bag		
	Total Number Aged	Number Juveniles	Per Cent Juveniles	Total Number	Number Juveniles	Per Cent Juveniles
1940–41	313	143	45.7	284	226	79.6
1941–42	398	274	68.8	79	50	63.3
1942–43	1,023	619	60.5	761	549	72.1
1943–44	2,329	1,379	59.2	173	158	91.3
1944–45	853	607	71.1	500	452	90.4
1945–46	310	196	63.2	857	689	80.4
1946–47	502	296	59 0	—	—	—
Total	*5,728*	*3,514*	—	*2,654*	*2,124*	—
Average			61 3			80.0

Table 24.—Productivity of the Horseshoe Lake flock as shown by trapping and bag-inspection ratios.[1]

Season	From Trapping					From Bag Inspection
	Total Number of Individuals Trapped of Known Age-Class and Sex[2]	Number of Breeding Adult Females Trapped[3]	Number of Juveniles Trapped	Juveniles per 100 Adult Females	Juveniles per 100 Yearlings and Adults	Juveniles per 100 Yearlings and Adults
1940–41	313	—	143	—	84	—
1941–42	408	—	274	—	204	—
1942–43	1,054	—	619	—	142	—
1943–44	2,462	—	1,379	—	127	126
1944–45	1,101	136	607	446	123	—
1945–46	541	88	196	223	57	—
1946–47	717	114	296	260	70	—
Total	*6,596*	*338*	*3,514*	*929*	*807*	
Average				325	114	

[1] See page 168 for explanation of reasons figures in this table differ from those in table 23.
[2] Numbers in this column include returns (geese banded in previous years)
[3] About 2½ or more years old at time of trapping.

juveniles to correct bag ratios for the disproportionate numbers of juveniles lost through shooting.

The vulnerability quotient of the juveniles is obtained by the following formula, suggested by Frank C. Bellrose:

$$\text{Vulnerability quotient } V = \frac{\dfrac{\text{Number of band recoveries from juveniles}}{\text{Number of juveniles banded before end of hunting season}}}{\dfrac{\text{Number of band recoveries from adults}}{\text{Number of adults banded before end of hunting season}}}$$

Data that are perhaps numerous enough to use in determining the vulnerability of the juveniles as compared with the vulnerability of the adults are available only for the 1943 hunting season.

In 1943:

$$V\frac{\text{Juvenile}}{\text{Adult}} = \frac{\dfrac{81}{754}}{\dfrac{6}{466}} = 8.34$$

According to these calculations, at Horseshoe Lake in 1943, the juveniles were 8.34 times as vulnerable to shooting as were the adults. With this figure available, it is possible, assuming the vulnerability quotient to be a true measure of vulnerability of the juveniles, to correct the age ratios obtained from bag inspection, which, by virtue of the higher vulnerability of the juveniles, is weighted in favor of this group as compared with the adult group in the total surviving population.

To correct age-ratio data obtained from bag inspection, it is assumed that the following formula is true, in which V is the vulnerability quotient calculated above from the trap and band-recovery data.

$$\text{Ratio } \frac{\text{Juveniles in population}}{\text{Adults in population}} = \frac{\dfrac{\text{Number of juveniles in bag}}{\text{Number of adults in bag}}}{V}$$

To solve for the juvenile-adult age ratio in the surviving population in 1943, the proper values from table 23 and the calculated V above are substituted in the formula.

$$\text{Ratio (1943)} \frac{\text{Juveniles}}{\text{Adults}} = \frac{\frac{158}{15}}{8.34}$$

$$\text{Ratio (1943)} \frac{\text{Juveniles}}{\text{Adults}} = \frac{10.53}{8.34} = 1.26$$

Then the corrected age ratio is 1.26 juveniles to 1.0 adult.

The ratio of juveniles to adults found above from corrected bag ratios for 1943 is close to the age ratio found from trapping for 1943 (127 juveniles to 100 adults, table 24). Over a 7-year period the juvenile age class comprised about 53 per cent of the birds in the Horseshoe Lake flock, table 24.

Not only is it important to know what percentage of the flock is composed of juveniles each year for a significant analysis of productivity; it is important to know also the production of young in relation to the number of mature females—birds that are 2½ or more years old when wintering at Horseshoe Lake. By relating productivity to only the sexually mature females, compensation can be made in statistical analyses of the flock for annual changes in the percentage of nonbreeding yearlings as well as for changes in ratio of adult males to adult females.

These productivity figures will be at variance with the impression that the average hunter gets from the flock at Horseshoe Lake. This hunter, on viewing the impressive concentration of geese at Horseshoe Lake, thinks that the total number of mated pairs in the flock in the following spring will equal the total population divided by two. Since he has heard that geese annually lay 5 or 6 eggs, he assumes that there will be an impressive increase for the next hunting season, and, thinking in terms of himself, anticipates more shooting. When informed that the flock may be even smaller in numbers at its peak in the autumn than it was at the close of shooting the previous year (as actually happened in the autumns of 1944 and 1945), in spite of the young added to the flock as a result of the breeding season, he may be dubious as to the competence of his informer.

The layman often fails to take into account the fact that Canada geese do not

Table 25.—Age and sex composition of the Horseshoe Lake flock, 1944–45 through 1946–47, as shown by trap catches of unbanded and previously banded geese.

Age and Sex Classification	Season						All Seasons	
	1944–45		1945–46		1946–47		Total Number Trapped	Per Cent
	Number Trapped	Per Cent	Number Trapped	Per Cent	Number Trapped	Per Cent		
Adult males[1]								
2½ years or more.	212	19.3	118	21.8	221	30.8	551	23.4
1½ years (yearlings).	96	8.7	75	13.9	44	6.1	215	9.1
Total	*308*	*28.0*	*193*	*35.7*	*265*	*36.9*	*766*	*32.5*
Adult females[2]								
2½ years or more	136	12.4	88	16.3	114	15.9	338	14.3
1½ years (yearlings)	50	4.5	64	11.8	42	5.9	156	6.6
Total	*186*	*16.9*	*152*	*28.1*	*156*	*21.8*	*494*	*20.9*
Juveniles								
Males	335	30.4	90	16.6	194	27.1	619	26.3
Females	272	24.7	106	19.6	102	14.2	480	20.3
Total	*607*	*55.1*	*196*	*36.2*	*296*	*41.3*	*1,099*	*46.6*
Grand total	*1,101*	*100.0*	*541*	*100.0*	*717*	*100.0*	*2,359*	*100.0*

[1] Aging techniques separating yearling males from males 2½ years old or older in fall and winter, about 85 per cent accurate.
[2] Aging techniques separating yearling females from females 2½ years old or older in fall and winter, about 99 per cent accurate.

breed until they are at least 2 or 3 years old, and that at least one-half of the birds he sees will still be sexually immature in the spring; that an excess of males exists in the birds of breeding age, table 25; that members of broken pairs may be slow to mate; that some pairs each year are not successful in rearing a family; and that natural losses as well as the Indian kill are taking place in the intervening months. The actual number of sexually mature females upon which production in the coming spring is dependent may comprise only a small segment of the winter flock, in some years as low as 12 to 17 per cent, table 25.

A rapid method of distinguishing yearlings from older geese, for use on live birds in the field, was not developed until the fall of 1944 (Hanson 1949*a*). Since the more nearly complete data from 1944–45 through 1945–46 were collected during and after hunting seasons in which higher rates of loss occurred among juveniles than among adults, the actual ratios of juveniles to breeding females existing *before* the shooting began would be somewhat higher than those indicated in table 24; the trap ratios in table 24 differ from the indicated ratios or percent-

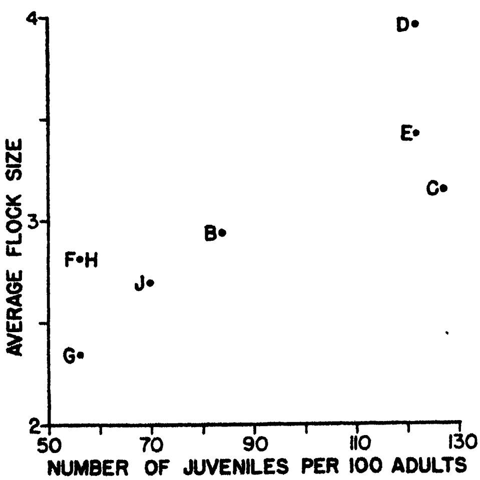

Fig. 73.—Relation of average flock size to productivity. Note that the average size of flocks in southern Wisconsin after light hunting losses was identical with the size of average flocks at Horseshoe Lake prior to hunting. *B-H* were derived mainly from data in fig. 64 and table 24. *J* represents data for 1946–47, shown in table 24 but not in fig. 64.

ages in table 23 only in the respect that the ratios in table 24 are based on the entire catch (exclusive of repeats) rather than on newly banded birds alone.

Theoretical vs. Actual Productivity

Data in the literature and from the captive flock at Bright Land Farm indicate that each pair of Canada geese would produce about 5 juveniles annually if all eggs laid were fertile, if all hatched, and if the young were raised to maturity without loss. Actual annual productivity, however, as indicated by the average brood sizes found in Utah and California, appears to be in the neighborhood of 3 to 4 young per nesting female or per pair. We have computed the ratio of juveniles to breeding females in the Horseshoe Lake flock as found from trapping. It was assumed that all females are sexually mature at about 2 years of age. The productivity of these females was computed from figures in table 24 to be, in 1944–45, 4.46, in 1945–46, 2.23, and, in 1946–47, 2.60 young per adult female.

Flock Sizes

Several decades ago, Phillips (1916) recorded his observations on the sizes of goose flocks in Massachusetts and presented evidence to show that in most instances these flocks were single families or groups of families. For flocks of less than 10 individuals, groups of six and seven individuals were most numerous; for flocks numbering between 10 and 30, groups that were multiples of five were most frequent. Unbroken families as large as 10, two adults and eight young, have been observed by the Miners at their refuge.

Flock counts have been made at Horseshoe Lake since 1941. Our analysis of these counts is limited to flocks of nine or less in number, because in this area a group of nine birds is the largest that we have observed to behave as a family unit. All individuals in this family, which were color-banded and of known age and sex, were repeatedly observed or trapped together.

Family-flock sizes at Horseshoe Lake and other areas for which we have data are shown in fig. 64. The frequency with which each family-flock size occurs is ex-

pressed as a percentage of the total observations.

From these data we suggest:

1. That the average family-flock size in late summer or early autumn may furnish a rough index of the age ratio within a large population, fig. 73; from this ratio the success of nesting the previous spring may be inferred, *A* and *D* in fig. 64.

2. That the average family-flock size in middle or late autumn, when compared with similar data gathered the same year before the opening of the hunting season, is indicative of the degree to which family groups have been broken through shooting. (Compare *F* and *G* in fig. 64.)

POPULATION SURVIVAL*

One of the objectives of the Canada goose research program reported in this paper was to determine through trapping and banding the annual mortality rate and the average longevity of Canada geese in the Horseshoe Lake flock in the period 1941–1946 and to compare the annual mortality data derived from the banding at Horseshoe Lake with similar data derived from the banding of Mississippi flyway geese at the Jack Miner Sanctuary in the period 1925–1944.

Definition of Terms

In the following discussion, *age class* refers to a group of geese, all of them hatched in a given year. A *banding class* includes all geese banded in a given season regardless of age at time of banding. The computed percentage of geese of a banding class alive each year in a series of successive years following banding comprises a *survival series.* This series may be computed from data in a *band-recovery series* (recoveries of bands from birds reported dead in any of several successive years after banding) or from data in a *trap series* (returns of banded birds to the traps in any of several successive years).

* The senior author is responsible for this section. As he carried out the trapping program at Horseshoe Lake and the compilation of the Miner recovery data in Ottawa, Canada, he is fully conscious of the inadequacies and bias in the data on which the following discussion is based. These inadequacies and bias do not permit the data to be treated by the customary methods. The methods used by-pass some of the shortcomings of the data, but, in the final analysis, the results presented only produce an approximation of the true picture. The reader should bear this point in mind in evaluating the results presented. It was deemed advisable to exploit the data as far as possible rather than disregard them altogether because of an acute awareness of their vagaries.

Table 26.—Hypothetical catches of Canada geese to illustrate difference between a trap series and a return series.

Season	Number of Geese Banded	Number of Banded Geese Returning: From 1 Year Ago	From 2 Years Ago	From 3 Years Ago	From 4 Years Ago
1942–43	*80*				
1943–44	100	*40*			
1944–45	100	55	*20*		
1945–46	**100**	**50**	**25**	***10***	
1946–47		50	25	10	*5*

Note.—The trap series is represented by **boldface** figures, to be read horizontally from left to right; the return series is represented by *italic* figures, to be read diagonally from left to right.

The difference between a trap series and that which we are here calling a *return series,* a series used by Leopold *et al.* (1943) to compute longevity and population turnover in ring-necked pheasants, is shown in table 26. The per cent of annual decrease in a population is here referred to as the *annual mortality rate.* The per cent of the population surviving from any 1 year to the year following is the *survival rate.* The *survival index* is the average of the survival rates for the first 3 years after banding.

Mortality

Survival rates or mortality rates in waterfowl may be computed from banding data by using either trap returns of survivors or band recoveries from dead birds. Reliability of calculations in either case increases as the number of bandings increases.

Mortality rates in the Horseshoe Lake flock were calculated from data obtained from both trap returns and band recoveries.* In juvenile-banded birds, mortality rates for the first year following banding were computed from age ratios derived from trapping and from census data.

Mortality Calculated From Trap Returns.—Mortality rates of the Horseshoe Lake flock as obtained from trap returns were derived both from returns of birds banded as juveniles, and therefore

* In the computations included in tables 34–41, band recoveries from the breeding grounds are not included because often the years of recovery are not known with certainty.

Table 27.—Approximate mortality of juvenile Canada geese during the first year after banding (year 0–1) at Horseshoe Lake, as determined by censuses and age ratios from trapping, 1943–44 through 1946–47.

Year Class	Estimated Size of Horseshoe Lake Flock*	Per Cent Juveniles in Trap Catches (See Table 24)	Calculated Number of Juveniles in Flock	Per Cent Yearlings in Trap Catches (See Table 25)	Calculated Number of Yearlings in Flock	Per Cent Survival of Juveniles of Previous Year
1943-44..	53,000	56.0	29,680			
1944-45	40,500	55.1	22,316	13.2	5,346	18.01
1945-46	29,100	36.2	10,534	25.7	7,479	33.51
1946-47	31,000			12.0	3,720	35.31
Total			*62,530*		*16,545*	
Average						26.46

*Method of estimating flock described on page 119. Per cent of error in censusing would be approximately the same for each year.

of a known age class, and from returns of birds of all ages, tables 27–33. They are based on the assumption that the number of individuals from each age class and banding class that return to the traps in any trapping season is approximately proportional to the total number alive of those same age and banding classes in the entire population. Thus, when trap returns in the same year of any two or more age or banding classes of geese banded in previous, successive years are expressed as percentages of each of the respective original bandings, the difference between these percentages is a measure of annual mortality. Average mortality rates in tables 30 and 33 are weighted averages based on data from bandings and trap returns in all years represented.

The method of deriving the weighted survival series is explained in footnotes to tables 29 and 32. The difference between successive survival series figures is a measure of annual mortality.

Table 28.—Trap returns of Canada geese banded as juveniles at Horseshoe Lake, 1940–41 through 1946–47.

Season	Number of Juveniles Banded	Returns in Designated Year Following Banding						Total
		1–2	2–3	3–4	4–5	5–6	6–7	
1940–41	143							
1941–42	274	1						1
1942–43	619	8	2					10
1943–44	1,379	67	13	3				83
1944–45	607	87	20	7	2			116
1945–46	196	106	35	8	5	0		154
1946–47		39	56	16	7	3	2	123
Total	*3,218*	*308*	*126*	*34*	*14*	*3*	*2*	*487*

When the numbers of geese of different but successive banding classes retrapped in any one later year are expressed as percentages of the original bandings, annual mortality rates, tables 30 and 33, can be calculated by the following formula:*

$$\text{Per cent mortality for year 1} = \frac{\text{Per cent returns in year 1} - \text{Per cent returns in year 2}}{\text{Per cent returns in year 1}}*$$

Because this method of computing mortality rates involves measuring the difference between the rates at which samples of two age or banding classes banded in successive years return to the traps in a later year, it cannot be used to compute mortality during the year of banding.

Age ratios secured from trapping at Horseshoe Lake, table 27, are perhaps sufficiently representative of the population to be useful in calculating the approximate survival of geese in their first year of life. It has been noted, however, that geese that have been attracted to the traps and banded as juveniles are more apt to return to the traps as yearlings the following year than are the geese banded as adults or yearlings. This tendency often

* Year 1 in formula represents any banding year except year of banding (as 2-3 in table 29); year 2 represents the next successive year (as 3-4 in table 29); returns for the same trapping season are used in making calculations, as 3.23 and 2.55 for 1944–45, table 29.

results in catches that are composed of disproportionately large numbers of banded yearlings in relation to the actual numbers of this age class in the untrapped portion of the population, with the result that calculated mortalities for yearlings, although seemingly very high, may be below the rates that actually occur in that age group in the unbanded segment of the population.

In table 28 the actual number of trap returns from geese banded as juveniles at Horseshoe Lake is given, and in table 29 these numbers have been converted into percentages of the original bandings. For example, 67 geese banded as juveniles in the trapping season of 1942–43 and 13 geese banded as juveniles in the season of 1941–42 were trapped in the winter of 1943–44, table 28. Expressed as percentages these returns were 10.82 and 4.74 per cent of the original bandings (619 and 274, respectively), table 29.

The survival series figures in tables 29 and 32 were derived from the weighted average per cent returns of geese of consecutive year classes, beginning with year 1–2 (first trapping season after year of banding). Tables 28, 29, and 30 include only juvenile-banded geese; tables 31, 32, and 33 include both juvenile-banded and adult-banded birds.

A more nearly accurate picture of survival in age classes than that given by table 29 begins with the 26.46 year-of-banding survival figure, table 27. Survival in subsequent years was derived from the weighted average per cent returns in table 29 through the formula explained in footnote 4 of that table; the survival series figure for the year previous to year 1–2 is assumed to be 26.46. For example, 9.57:4.17::26.46:x; x is 11.53, the survival series figure for the year 1–2. The entire survival series is 26.46, 11.53, 3.90, 3.73, 1.99, 3.87, fig. 74. The weighted average survival rates, as calculated from this survival series by the method suggested

Table 29.—Trap returns of Canada geese banded as juveniles at Horseshoe Lake, expressed as percentages of original bandings, 1940–41 through 1946–47.

SEASON	PER CENT OF GEESE RETURNING IN DESIGNATED YEAR FOLLOWING BANDING					
	1–2	2–3	3–4	4–5	5–6	6–7
1940–41	—					
1941–42	0.70					
1942–43	2 92	1.40				
1943–44	10.82	4.74	2.10			
1944–45	6.31	3 23	2.55	1 40		
1945–46	17 46	2.54	1 29	1 82	0 00	
1946–47	19.90	9 23	1 16	1 13	1.09	1.40
Weighted average per cent returns[1]	9 57	4.17	1 41	1 35	0.72	1 40
Weighted survival series, no. 1[2]	51.40	22.40	7.57	7 25	3.87	7.52
Weighted average survival rates, no. 1[3]	51 40	43.58	33 79	95 77	53.38	194 32
Weighted survival series, no. 2[4]	43 57	14.73	14.10	7 52	14 62	—
Weighted average survival rates, no. 2[5]	43 57	33 81	95.72	53.33	194.41	—
Survival index, 42 92[6]						

[1] Total of weighted average per cent returns, 18.62. Figures in this category were derived from table 28. The total number of trap returns for each year is expressed as a percentage of the total number of bandings they represent. For example, 308 (returns for year 1–2) equals 9.57 per cent of 3,218 (bandings, 1940–41 through 1945–46); 126 (returns for year 2–3) equals 4.17 per cent of 3,022 (bandings, 1940–41 through 1944–45).

[2] Figures in this category were derived by finding what per cent the weighted average per cent returns for each year are of the weighted average per cent returns for all years involved (18.62). Example: for year 4–5, the figure 7.25 was derived by finding what per cent 1.35 is of 18.62. The indicated increase for year 6–7 obviously is based upon insufficient data.

[3] The figure in this category for year 1–2 was derived as explained for the figure directly above it. Figures for subsequent years were derived by finding the per cent of survival from year to year, as indicated by the weighted survival series no. 1. Examples: 22.40 is 43.58 per cent of 51.40; 7.57 is 33.79 per cent of 22.40.

[4] Figures in this series were derived by the following formula, in which *a*, *b*, and *c* are any consecutive years: *weighted average returns in year b: weighted average returns in year c:: survival series no. 2 figure for year a: survival series no. 2 figure for year b (x).* Example: 1.41:1.35::14.73:x; x=14.10. The survival series no. 2 figure for the year previous to year 1–2 is assumed to be 100.

[5] The figure in this category for year 1–2 was derived as explained for the figure directly above it. Figures for subsequent years were derived by finding the per cent of survival from year to year, as indicated by weighted survival series no. 2. Examples: 14.73 is 33.81 per cent of 43.57; 14.10 is 95.72 per cent of 14.73.

[6] Average of weighted average survival rates no. 1 for the first 3 years.

Table 30.—Annual mortality rates (per cent) of juveniles in the Canada goose flock at Horseshoe Lake, 1940–41 through 1946–47. (See formula, page 173, and data in table 29, top).

SEASON	MORTALITY RATE IN DESIGNATED YEAR FOLLOWING BANDING				
	0–1[1]	1–2	2–3	3–4	4–5
1940–41	—				
1941–42	—				
1942–43	—	52			
1943–44	82	56	56		
1944–45	66	49	21	45	
1945–46	65	85	49	—41[2]	100
1946–47	—	54	87	3	3
Weighted average mortality[3]	*74*	*56*	*66*	*4*	*47*

[1] Figures in this column calculated from figures in column 7, table 27.
[2] Increase in population indicated; inadequate data.
[3] Figures derived by subtracting from 100 each of weighted average survival rates mentioned in text, page 175.

in footnote 5 of table 29, are 26.46, 43.58, 33.82, 95.64, 53.35, and 194.47. The

Table 31.—Total catches and trap returns of banded Canada geese of all ages at Horseshoe Lake, 1940–41 through 1946–47.

SEASON	NUMBER CAUGHT AND BANDED OF ALL AGES	GEESE RETURNING IN DESIGNATED YEAR FOLLOWING BANDING						TOTAL
		1–2	2–3	3–4	4–5	5–6	6–7	
1940–41	315	—						
1941–42	402	6						6
1942–43	1,036	14	4					18
1943–44	2,329	99	20	14				133
1944–45	853	194	37	10	7			248
1945–46	310	131	84	11	5	0		231
1946–47	—	65	72	55	12	7	4	215
Total	*5,245*	*509*	*217*	*90*	*24*	*7*	*4*	*851*

survival index, not entirely comparable to survival indices in tables 29 and 32, is 34.62.

The weighted average mortality rate for each year of life following banding can be derived from the weighted survival series after computing the per cent of

Table 32.—Trap returns of banded Canada geese of all ages at Horseshoe Lake, expressed as percentages of original bandings, 1940–41 through 1946–47.

SEASON	PER CENT OF GEESE RETURNING IN DESIGNATED YEAR FOLLOWING BANDING					
	1–2	2–3	3–4	4–5	5–6	6–7
1940–41	—					
1941–42	1.90					
1942–43	3.48	1.27				
1943–44	9.55	4.97	4.44			
1944–45	8.33	3.57	2.49	2.22		
1945–46	15.36	3.61	1.06	1.24	0.00	
1946–47	20.97	8.44	2.36	1.16	1.68	1.27
Weighted average per cent returns[1]	9.70	4.39	2.20	1.37	0.98	1.27
Weighted survival series, no. 1[2]	48.72	22.05	11.05	6.88	4.92	6.38
Weighted average survival rates, no. 1[3]	48.72	45.26	50.11	62.26	71.51	129.67
Weighted survival series, no. 2[4]	45.26	22.68	14.12	10.10	13.09	—
Weighted average survival rates, no. 2[5]	45.26	50.11	62.26	71.53	129.60	—
Survival index, 48.03[6]						

[1] Total of weighted average per cent returns, 19.91. Figures in this category were derived from table 31. The total number of trap returns for each year is expressed as a percentage of the total number of bandings they represent. For example, 509 (returns for year 1–2) equals 9.70 per cent of 5,245 (bandings, 1940–41 through 1945–46); 217 (returns for year 2–3) equals 4.39 per cent of 4,939 (bandings, 1940–41 through 1944–45).
[2] Figures in this category were derived by finding what per cent the weighted average per cent returns for each year are of the weighted average per cent returns for all years involved (19.91). Example. for year 3–4, the figure 11.05 was derived by finding what per cent 2.20 is of 19.91. Indicated increase for year 6–7 is based upon insufficient data.
[3] The figure in this category for year 1–2 was derived as explained for the figure directly above it. Figures for subsequent years were derived by finding the per cent of survival from year to year, as indicated by the weighted survival series no. 1. Example. 22.05 is 45.26 per cent of 48.72; 11.05 is 50.11 per cent of 22.05.
[4] Figures in this series were derived by the following formula, in which *a, b,* and *c* are any consecutive years: *weighted average returns in year b: weighted average returns in year c:: survival series no. 2 figure for year a: survival series no. 2 figure for year b (x).* Example: 1.37:0.98::14.12:x; x=10.10. The survival series no. 2 figure for the year previous to year 1–2 is assumed to be 100.
[5] The figure in this category for year 1–2 was derived as explained for the figure directly above it. Figures for subsequent years were derived by finding the per cent of survival from year to year, as indicated by weighted survival series no. 2. Examples: 22.68 is 50.11 per cent of 45.26; 14.12 is 62.26 per cent of 22.68.
[6] Average of weighted average survival rates for the first 3 years.

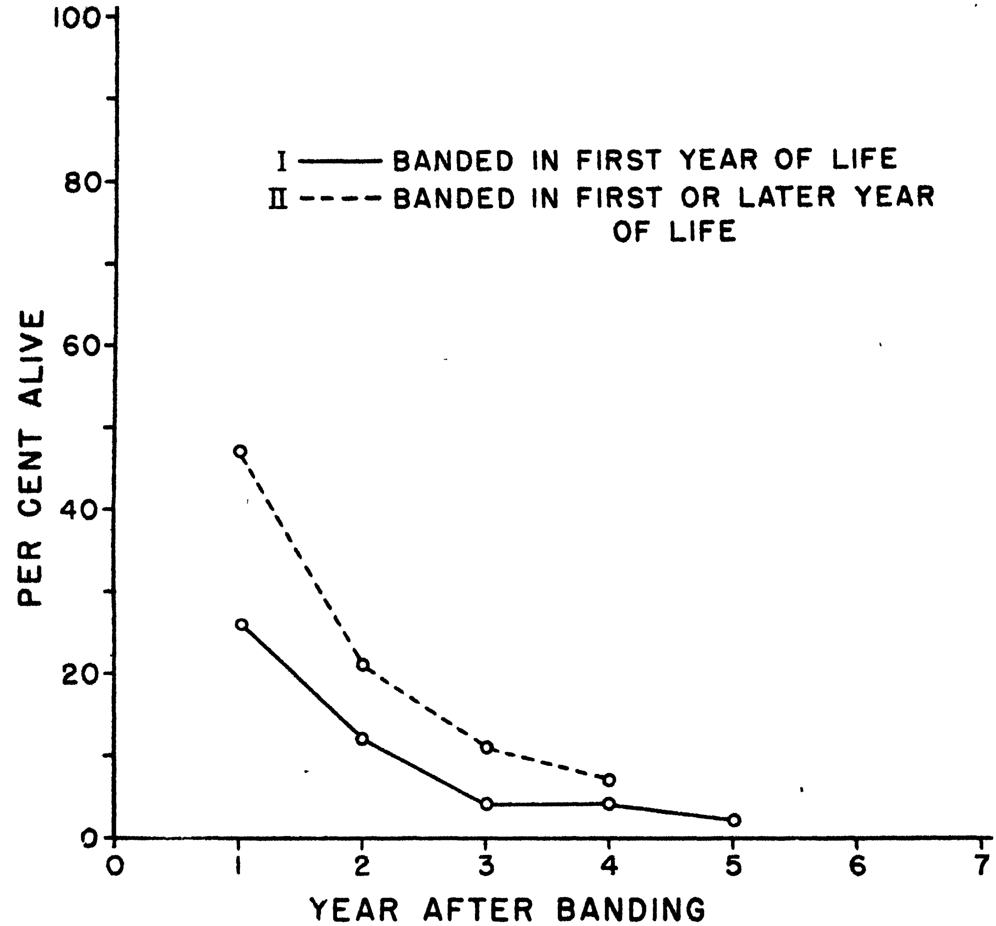

Fig. 74.—Survival of two groups of Canada geese, one banded in first year of life and one banded in first or later year of life. Curve I figures are from page 174; Curve II figures are from table 32, survival series 1.

geese remaining alive in each successive year. The survival rates cited above indicate that an average of 74 per cent of the original bandings disappeared by the end of the year of banding, 56 per cent of the survivors were lost during the second year after banding, 66 per cent the third year, 4 per cent the fourth year, and 47 per cent the fifth year, table 30.

Data on returns from banded geese of all ages, that is, the combined returns of birds banded as juveniles, yearlings, and geese of unknown age, have been treated in the manner described above, tables 31, 32, and 33. The survival series obtained, 49–22–11–7–5, table 32 and fig. 74, is believed to represent the approximate rate at which the average banding class in the Horseshoe Lake flock disappeared during the first 5 years of life following banding in the trapping seasons 1940–41 through 1946–47. The disproportionate loss of juveniles that usually occurs, in large part from shooting, does not weight this portion of the survival series, since the series is based on the total per cent of the geese returning to the traps 1 or more years after banding. The weighted average per cent return, 9.70, table 32, of geese the first year after the year of banding necessarily represents birds that are at least 1½ years of age.

The calculation methods discussed above leave much to be desired, particularly those involving mortality rates of the juveniles during the first year of life after

Table 33.—Annual mortality rates (per cent) in the Canada goose flock wintering at Horseshoe Lake, 1940–41 through 1946–47. (See formula, page 173, and data in table 32, top.)

Season	Mortality Rate in Designated Year Following Banding				
	1–2	2–3	3–4	4–5	5–6
1940–41	—				
1941–42	—				
1942–43	63				
1943–44	48	11			
1944–45	57	30	11		
1945–46	76	71	–17[1]	100	
1946–47	60	72	51	–45[1]	24
Weighted average mortality[2]	*55*	*50*	*38*	*28*	*–30*[3]

[1] Increase, instead of decrease, indicated because of disproportionate return to traps of banding class.
[2] Derived from table 32 by subtracting each survival rate no. 2 figure from 100.
[3] Figure based on insufficient data.

banding as derived from census data and trap-age ratios. However, we know, because of the heavy kills made at Horseshoe Lake and the high differential vulnerability of juveniles, that the juvenile component of the population suffered tremendous annual hunting losses during the period of field work.

The computed average mortality rate of 74 per cent during the first year following banding, table 30, is probably not far from the average mortality rate that actually occurred.

The fate of each banding class could not be traced through successive years because it was obviously impossible to trap all the banded survivors, and it was equally impossible to correct for the number of banded survivors that could not be retrapped, since the banded population was never well intermixed in the

Table 34.—Number of band recoveries from Canada geese banded at Kingsville, Ontario, and recovered in the states of Michigan, Wisconsin, Ohio, Indiana, Illinois, Iowa, Kentucky, Tennessee, Missouri, Arkansas, Mississippi, and Louisiana. (Autumn bandings only.)

Year Banded	Recoveries in Designated Year Following Banding												
	0–1	1–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–10	10–11	11–12	12–13
1925	(9)	6	10	6	*3*	**4**	0	0	3	0	0	0	0
1926	(12)	11	5	*3*	**3**	0	0	0	0	0	0	0	0
1927	(2)	3	*4*	**3**	0	0	0	1	0	0	0	0	0
1928	(7)	*23*	**8**	0	7	2	0	0	3	0	1	1	0
1929	(7)	**13**	1	4	1	0	0	1	0	0	0	0	0
1930	(20)	4	8	7	*9*	**3**	1	0	0	0	2	0	0
1931	(1)	35	26	*12*	**3**	1	1	2	3	2	0	1	0
1932	(21)	31	*10*	**1**	3	1	1	2	2	0	0	1	0
1933	(25)	*24*	**3**	2	3	3	6	1	0	0	0	0	0
1934	(*18*)	**6**	1	4	2	6	3	0	1	1	0	0	
1935	(1)	1	2	1	*0*	**2**	1	0	0	0	0		
1936	(1)	10	7	*6*	**8**	2	1	1	2	0			
1937	(9)	17	*34*	**21**	5	7	6	8	0				
1938	(2)	*13*	**9**	2	2	9	0	3					
1939	(*7*)	**35**	11	3	9	4	0						
1940	(32)	11	4	2	*3*	**1**							
1941	(2)	12	12	*9*	**6**								
1942	(4)	9	*6*	**0**									
1943	(10)	*11*	**7**										
1944	(*6*)	**15**											

NOTES ON TABLE 34

Numerals indicating recoveries made during the year of banding are enclosed in parentheses.

Solid horizontal lines divide this table into four 5-year periods, treated in several tables following.

Recoveries for the years above the broken horizontal line are considered complete; they are treated in table 35 and expressed graphically in fig. 75.

Figures to the left of the single vertical rule are treated in table 36 and expressed graphically in fig. 76.

Figures to the left of the double vertical rule are treated in table 40 and expressed graphically in fig. 79.

Italicized figures and those above to the next solid horizontal line are treated in table 37, and the resultant survival series is shown graphically in fig. 77.

Boldface figures and those above to the next solid horizontal line are treated in table 39, and the resultant survival series is shown graphically in fig. 78.

Table 35.—Recoveries in the Mississippi River valley of bands from Canada geese banded at Kingsville, Ontario, in the autumn, 1925–1932. The recoveries are for 12 years, including the year of banding.[1]

1925–1932 Bandings	Recoveries in Designated Year Following Banding												
	0[2]	0–1	1–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–10	10–11	11–12
Bands recovered.....	0	79	126	72	36	29	11	3	6	11	2	3	3
Bands not recovered.	381	302	176	104	68	39	28	25	19	8	6	3	0
Survival series[3]......	100	79	46	27	18	10	7	7	5	2	2	1	0
Survival rate[4].......	.....	79	58	59	65	57	72	89	76	42	75	50	0

[1] Data in this table were derived from table 34; included are the sums of figures in table 34 *for the period 1925–1932* in the several columns representing year of banding and years 1–2 through 11–12 following banding.
[2] Time of banding. The 381 in the column below represents the total of the number of bands recovered in the 12 years included in the table. No correction made for differences in times of banding in year 0–1.
[3] Survival series figures are derived by finding the total number of bands recovered and then calculating what percentage the number of *bands not recovered* in each year is of the total number of recoveries; for example, for year 1–2, the number 176 is divided by 381 to give 46.
[4] Survival rate figures are derived by calculating what percentage the number of *bands not recovered* in each year is of the number of *bands not recovered* in the preceding year; for example, for year 2–3, the number 104 is divided by 176 to give 59.

flock as a whole. The reasons that the banded component was not well intermixed were (1) the tendency of many banded individuals to use the same sector of the refuge during the season of band-

Table 36.—Recoveries in the Mississippi River valley of bands from Canada geese banded at Kingsville, Ontario, by three 5-year periods, 1925–1939. The recoveries are for 6 years and include the year of banding.[1]

	Recoveries in Designated Year Following Banding						
	0[2]	0–1	1–2	2–3	3–4	4–5	5–6
1925–1929 Bandings							
Bands recovered ...	0	37	56	28	16	14	6
Bands not recovered.	157	120	64	36	20	6	0
Survival series[3].	100	76	41	23	13	4	0
Survival rate[4].....	—	76	53	56	56	30	
1930–1934 Bandings							
Bands recovered ...	0	85	100	48	26	20	14
Bands not recovered.	293	208	108	60	34	14	0
Survival series[3]. .	100	71	37	20	12	5	0
Survival rate[4]	—	71	52	56	57	41	
1935–1939 Bandings							
Bands recovered....	0	20	76	63	33	24	24
Bands not recovered	240	220	144	81	48	24	0
Survival series[3]......	100	92	60	34	20	10	0
Survival rate[4]... ..	—	92	65	56	59	50	

[1] Data in this table were derived from table 34; included are the sums of figures in table 34 *for three 5-year periods*, 1925–1939, in the several columns representing year of banding and years 1–2 through 5–6 following banding.
[2] See footnote 2, table 35.
[3] See footnote 3, table 35.
[4] See footnote 4, table 35.

Table 37.—Recoveries in the Mississippi River valley of bands from Canada geese banded at Kingsville, Ontario, by 5-year periods, 1925–1944. The recoveries are for the year of banding and parts of the 4 years following.[1]

	Recoveries in Designated Year Following Banding					
	0[2]	0–1	1–2	2–3	3–4	4–5
1925–1929 Bandings						
Bands recovered .	0	37	43	19	9	3
Bands not recovered....	111	74	31	12	3	0
Survival series[3]	100	67	28	11	3	0
1930–1934 Bandings						
Bands recovered..	0	85	94	44	19	9
Bands not recovered ...	251	166	72	28	9	0
Survival series[3] .	100	66	29	11	4	0
1935–1939 Bandings						
Bands recovered..	0	20	41	43	7	0
Bands not recovered......	111	91	50	7	0	0
Survival series[3]...	100	82	45	6	0	0
1940–1944 Bandings						
Bands recovered..	0	54	43	22	14	3
Bands not recovered......	133	79	36	14	3	0
Survival series[3] .	100	59	27	11	2	0

[1] Data in this table were derived from table 34; included are figures obtained by adding each column of figures in each of four 5-year periods from top downward through the *italicized* figures. For instance, for year 3–4 in the first 5-year period, the figures 6 and 3 are added.
[2] See footnote 2, table 35.
[3] See footnote 3, table 35.

ing, as well as during subsequent banding seasons, and (2) the tendency of some individuals to establish a trap habit that persisted in later years.

For several reasons it seemed desirable to make an "across the board" treatment of the trap data, that is, an analysis of mortality from annual random samplings of the retrapped banded survivors. Tables 28–33, referring to trap returns, should be read horizontally; they should not be read diagonally, as they would be if a single banding class were followed through the years.

A few geese banded at Horseshoe Lake winter in parts of the Mississippi flyway other than at this lake, and while some disperse to other flyways, table 4, there is no evidence that this dispersal to a different wintering range is greater during any particular year than in others, a factor that might otherwise seriously influence the validity of our survival series.

Mortality Calculated From Band Recoveries.—The survival rate measured by the use of band recoveries is based on the assumption that the unbanded segment of a population disappears at approximately the same rate as the banded segment and that year-to-year differences in the numbers of banded birds reported dead in successive years is indicative of the annual mortality of the entire population. However, unless all banding is

Table 38.—Recoveries in the Mississippi River valley of bands from Canada geese of all age classes banded at Horseshoe Lake, 1940–41 through 1944–45.

Trapping Season	Recoveries in Designated Year Following Banding					
	0–1[1]	1–2	2–3	3–4	4–5	5–6
1940–41	—	15	7	11	3	2
1941–42	—	10	10	7	1	
1942–43	—	40	17	10		
1943–44	—	39	36			
1944–45	—	15				
Bands recovered	—	119	70	28	4	2
Bands not recovered	223	104	34	6	2	0
Survival series[2]	100	47	15	3	1	0

[1] Year of banding; recoveries in this year not included in calculations in table.
[2] Survival series calculated as described in footnote 3, table 35.

Table 39.—Recoveries in the Mississippi River valley of bands from Canada geese banded at Kingsville, Ontario, in four 5-year periods, 1925–1944. The recoveries are for parts of the first 5 years following the year of banding.[1]

	Recoveries in Designated Year Following Banding					
1925–1929 Bandings	0–1[2]	1–2	2–3	3–4	4–5	5–6
Bands recovered	—	56	27	12	6	4
Bands not recovered	105	49	22	10	4	0
Survival series[3]	100	46.7	21 0	9 5	3.8	0
1930–1934 Bandings						
Bands recovered	—	100	47	20	12	3
Bands not recovered	182	82	35	15	3	0
Survival series[3]	100	45 0	19 2	8 2	1 6	0
1935–1939 Bandings						
Bands recovered	—	76	52	28	8	2
Bands not recovered	166	90	38	10	2	0
Survival series[3]	100	54 2	22 9	6 0	1.2	0
1940–1944 Bandings						
Bands recovered	—	58	29	11	9	1
Bands not recovered	108	50	21	10	1	0
Survival series[3]	100	46 3	19 4	9 3	0 9	0

[1] Data in this table were derived from table 34; included are figures obtained by adding each column of figures in each of four 5-year periods from top downward through the boldface figures. For instance, for year 3–4 in the first 5-year period, the figures 6, 3, and 3 are added.
[2] Year of banding. Recoveries in this year not included in calculations in table.
[3] Survival series calculated as described in footnote 3, table 35.

completed before the opening of the hunting season, the first-year recoveries will be too few and the entire survival series too high. This criticism is valid for the survival series in tables 36 and 37, in which first-year recoveries are included in the computations to make relative comparisons of survival rates.

In the computation of a survival series from band recoveries, the recoveries may be treated in either of two primarily different ways: (1) the recoveries for each year may be expressed as a percentage of the number of geese banded; or (2) the recoveries may be totaled to give the hypothetical original number of banded birds alive at the start of the first year following banding, and then the number of re-

coveries reported during each succeeding year after banding is subtracted from the number of banded geese unrecovered and presumably alive the preceding year; then the number of geese unrecovered and assumed to be alive in each year is expressed as a per cent of the total recoveries, table 35. The second method must be used for recovery data from bandings at Kingsville, Ontario, because the size of the original banding is not known with certainty and because an unknown portion of the bandings listed in table 2 were Mississippi Valley geese; presumably the remainder represented the Southeast population.

For the purpose of comparing mortality in another segment of the Mississippi Valley population since 1925 with mortality in the Horseshoe Lake flock, recoveries of geese banded at the Jack Miner Bird Sanctuary in the autumn were used, table 34. Although band recoveries from geese of unknown age at the time of banding do not give a precise picture of population mortality in Canada geese because of the differentially high kill of the juveniles by hunters, they suffice as a basis for a com-

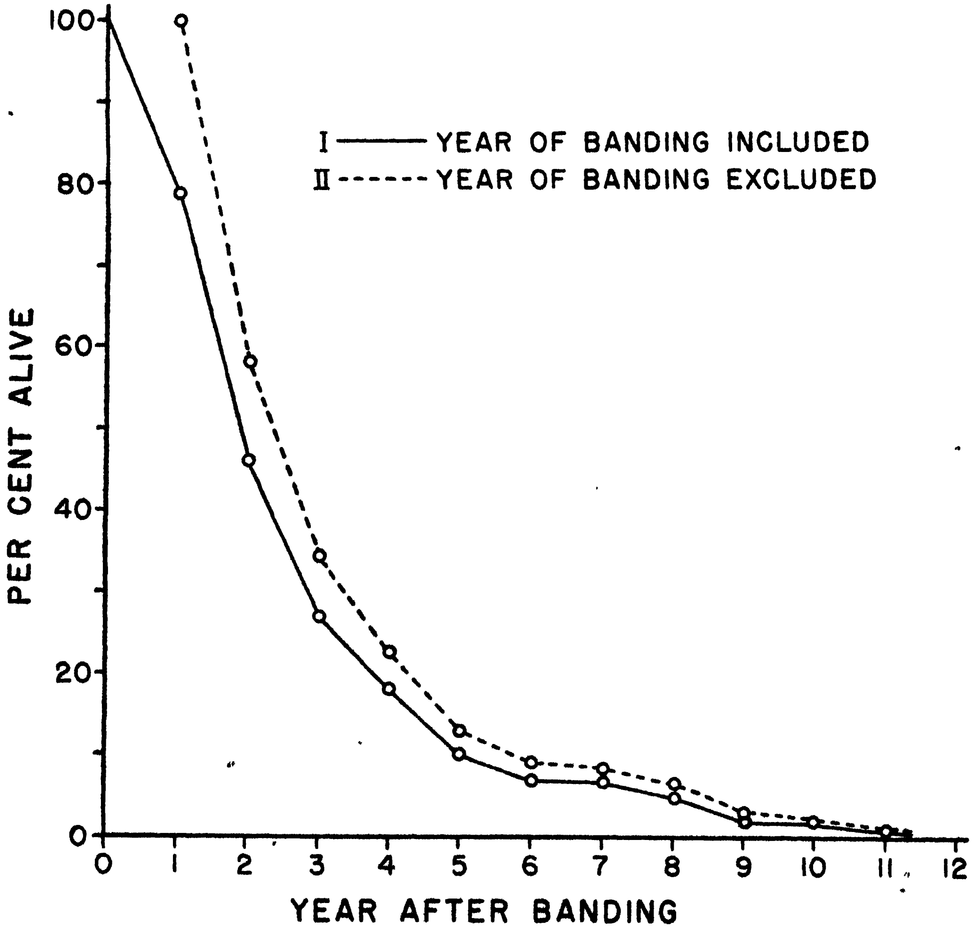

Fig. 75.—Average survival of Mississippi Valley Canada geese, as measured by band recoveries from geese banded at the Jack Miner Bird Sanctuary, Kingsville, Ontario, in the autumn, 1925–1932. Curve I includes band recoveries made during the year of banding; curve II excludes recoveries made during the year of banding. Curve I (data from table 35) starts with an expression (100 per cent) of the total number of recovered bands; curve II (data from table 41) starts with an expression (100 per cent) of the total number of recovered bands that were on geese alive at the beginning of the year following banding.

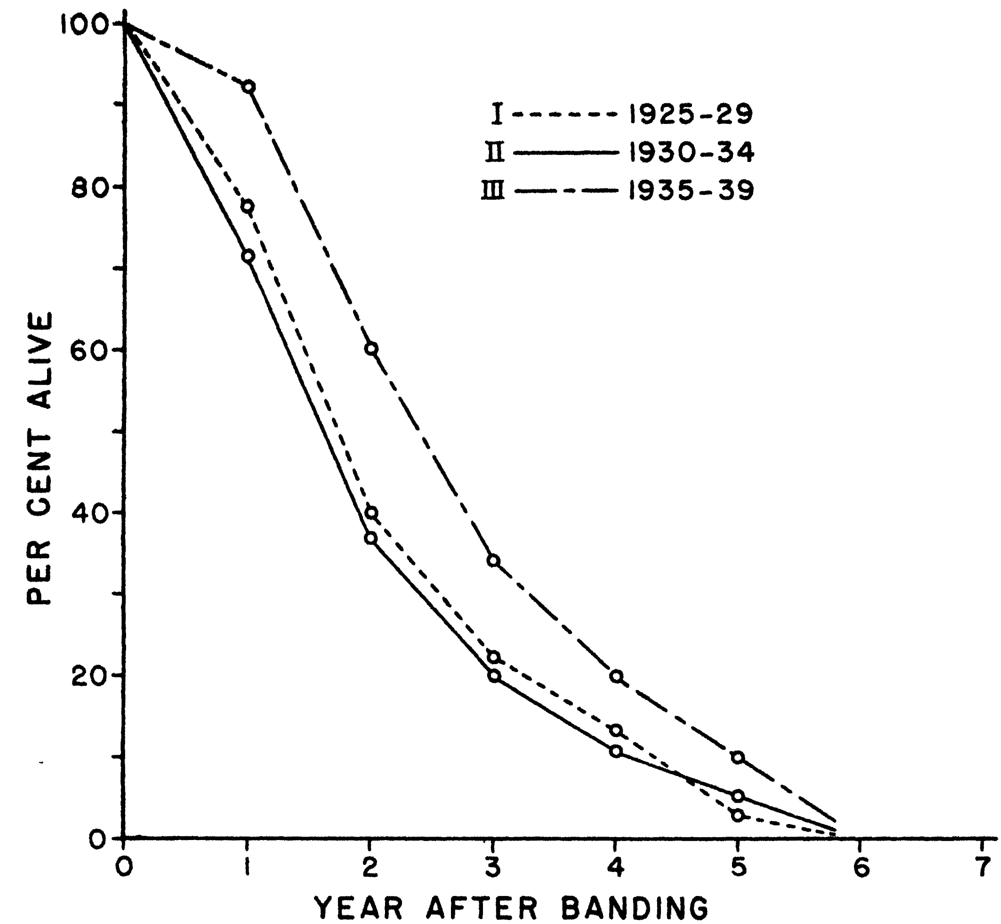

Fig. 76.—Average survival of Mississippi Valley Canada geese, as measured by band recoveries from geese banded at the Jack Miner Bird Sanctuary, in the autumn, 1925-1939. That part of each curve representing the year of banding shows a higher rate of survival than actually occurred, as in the data (from table 36), which represent the number of bands recovered and not the number of bands applied; no correction was made for the varying lengths of exposure to guns experienced by geese banded at various times in the season of banding.

parison of mortality rates in different years. As no individuals from the Miner autumn bandings have been reported shot in the Mississippi River valley later than 12 years after banding, recoveries of geese banded in 1925–1932 may be considered nearly 100 per cent complete by 1944. These data, summarized in table 35 and presented graphically in fig. 75, curve I, show that maximum survival in Canada geese in the Mississippi River valley under moderate hunting pressure is about 12 years.

Since about 93 per cent of the bands in the 12-year series were recovered by the end of the sixth or seventh years after banding, table 35, no great error would result from basing an analysis of mortality from 1925 through 1939 on the number of banded geese reported dead by the end of the sixth or seventh years. Recoveries of birds banded in those years are grouped by three 5-year periods. These 5-year data groups are set off by horizontal lines in table 34. In table 36, they have been summarized. The survival curves based on these data are shown graphically in fig. 76.

In order to compare the survival of geese banded at the Miner Sanctuary in

1940–1944 with the survival achieved by geese banded by the Miners in previous years, it was necessary to use an incomplete band-recovery series, derived from table 34, as explained in a footnote to table 37. The groupings for this analysis are summarized in table 37 and the computed survival curves are shown in fig. 77.

First-year survival data obtained from recoveries of geese banded at the Miner Sanctuary in the autumn are not an accurate representation of average first-year survival for Mississippi flyway geese as a whole. Whereas most bandings of waterfowl yield the greatest number of recoveries during the year of banding, the largest number of recoveries from Miner bandings have been received in most instances the year following the year of banding, table 34. One reason for this situation may be that the geese that are trapped and banded represent those that remain at the sanctuary the longest; this explanation is supported by migration data. Late south-bound migrants tend to remain longer in the more northerly sectors of the autumn and winter range than do the early migrants. Furthermore, most of the geese banded at the Miner Sanctuary in the autumn are trapped in November and December, when the hunting season in the northern and central zones of the

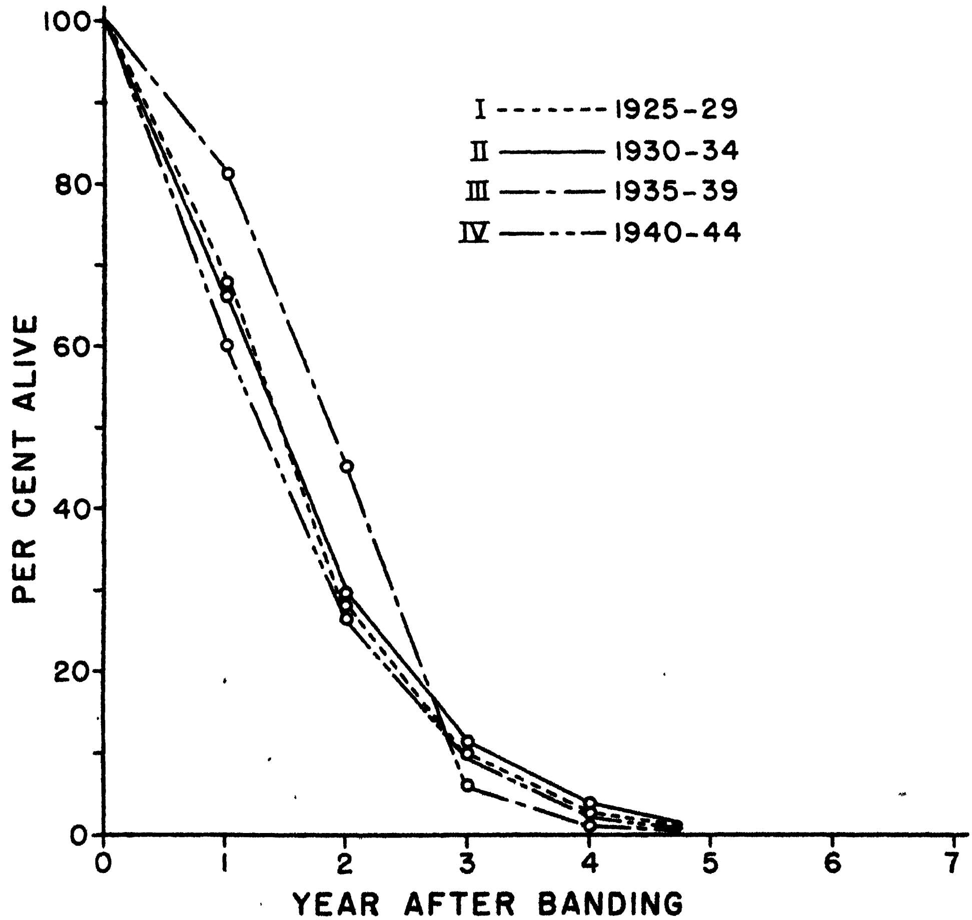

Fig. 77.—Comparative survival of Mississippi Valley Canada geese in four 5-year periods. Curves are based on band recoveries from geese banded at the Miner Sanctuary in the autumn (data from table 37, which include recoveries in year of banding). Curves start with an expression (100 per cent) of total number of bands recovered, not total number placed on geese.

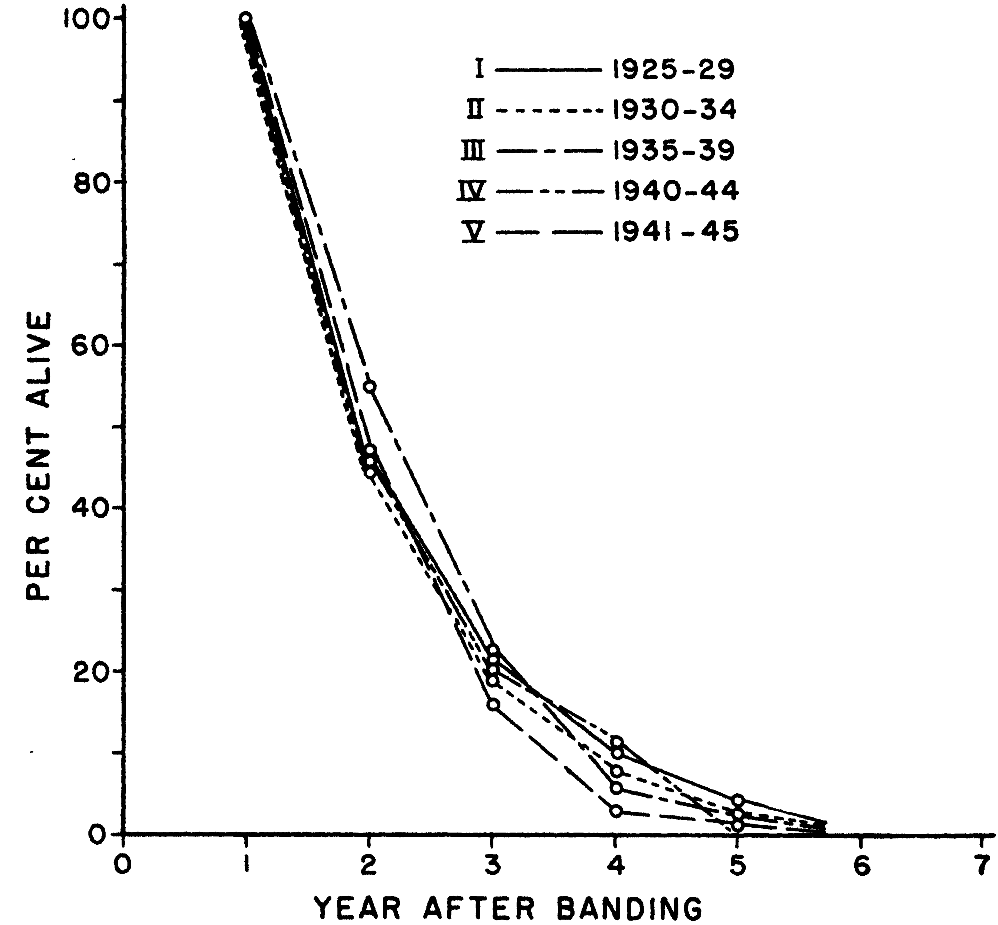

Fig. 78.—Comparative survival in three 5-year periods of Mississippi Valley Canada geese that were at least 1½ years old (the year after being banded). Curves I–IV are based on data from table 39, bandings at Kingsville, Ontario. Curve V is based on data from table 38, bandings at Horseshoe Lake. All curves start with an expression (100 per cent) of the total number of recovered bands that were on geese alive at the beginning of the year following banding.

Mississippi flyway is at least half over. Nevertheless, these data demonstrate something of the magnitude of the *relative* differences of survival of the various quinquennial groupings, either graphically or expressed as survival indices.

Because the Canada goose population wintering at Horseshoe Lake constitutes a somewhat different representation of the Mississippi Valley population than do the geese banded in the autumn at the Miner Sanctuary (demonstrated by the fact that geese banded at Horseshoe Lake are shot farther north on the breeding range than are geese banded at Kingsville, Ontario, fig. 7), it is of interest to compare the band-recovery data from these two banding stations through the season 5–6 after banding, the last season for which data are available for both stations.

When this comparison of mortality rates is made, it is desirable to omit recoveries made during the season of banding, since the time of banding, the location of the banding station, and the circumstances immediately following banding are not comparable. The recovery data from the Horseshoe Lake flock are

given in table 38 and the recovery data from the Miner bandings for a comparable number of years are summarized in table 39. The survival series derived from tables 38 and 39 are presented graphically in fig. 78.

Inspection of the curves in fig. 78 reveals that the differences between curves I and IV are not so great as between comparable curves shown in fig. 77. The probable explanation is that all recoveries shown graphically in fig. 78 represent geese at least 1½ years old, whereas the survival series that includes recoveries during the season of banding are in part from juvenile geese. Since the latter age class is far more vulnerable to shooting than older geese, recoveries from a banded population that includes juveniles would naturally reflect more sensitively the severity of hunting losses in various seasons. For this reason curve V in fig. 78, which is based on data presented in table 38, does not adequately reflect the tremendous and disproportionate kill of juveniles in the vicinity of Horseshoe Lake from 1943 through 1945.

In table 40, recoveries of bandings, 1925–1939, complete through season 6–7 after banding, but omitting recoveries the

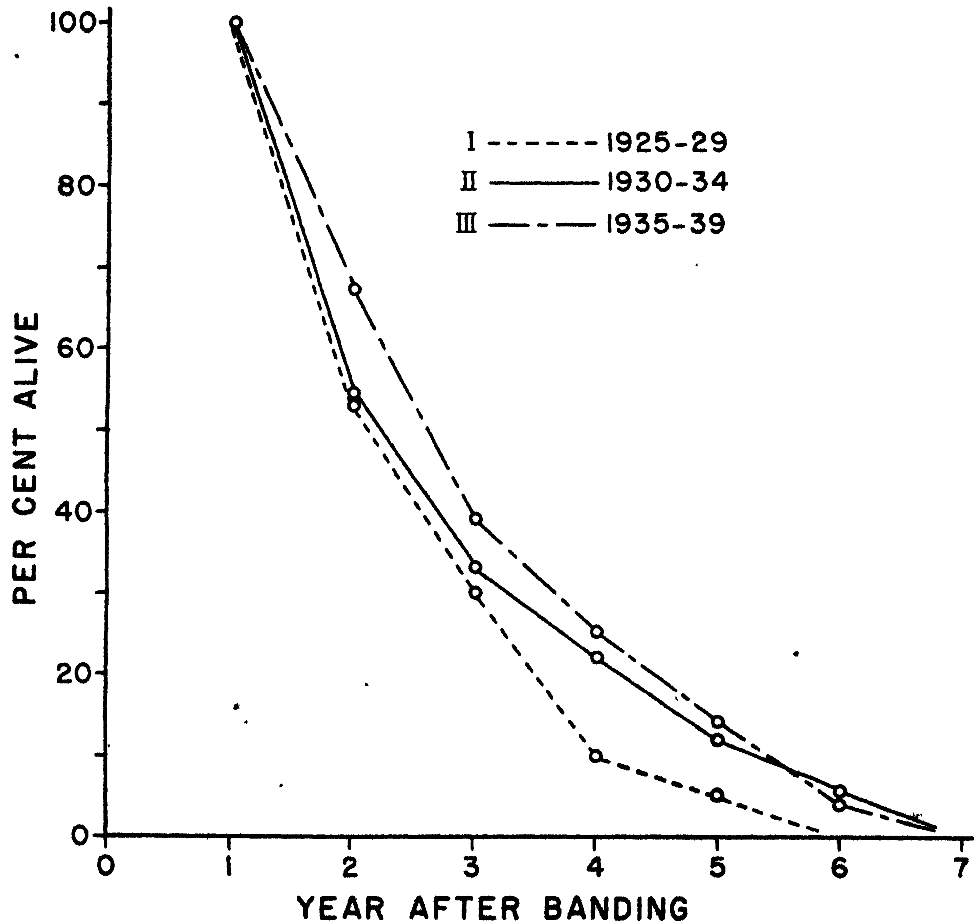

Fig. 79.—Comparative survival (in four 5-year periods) of Canada geese that were at least 1½ years old (the year after being banded). Curves are based on recovery data from table 40, bandings at Kingsville, Ontario. All curves start with an expression (100 per cent) of the total number of recovered bands that were on geese alive at the beginning of the year following banding.

Table 40.—Recoveries in the Mississippi River valley of bands from Canada geese banded at Kingsville, Ontario, in three 5-year periods, 1925–1939. The recoveries are for the first 6 years following the year of banding.[1]

	RECOVERIES IN DESIGNATED YEAR FOLLOWING BANDING						
1925–1929 BANDINGS	0–1[2]	1–2	2–3	3–4	4–5	5–6	6–7
Bands recovered...	—	56	28	16	14	6	0
Bands not recovered.	120	64	36	20	6	0	0
Survival series[3] . .	100	53.3	30.0	10.0	5.0	0	0
Survival rate[4].	—	53.3	56.3	33.3	50.0	0	0
Survival index, 47.6[5]							
1930–1934 BANDINGS							
Bands recovered	—	100	48	26	20	14	12
Bands not recovered.	220	120	72	46	26	12	0
Survival series[3]	100	54.5	32.7	20.9	11.8	5.5	0
Survival rate[4]	—	54.5	60.0	63.9	56.5	46.2	0
Survival index, 59.5[5]							
1935–1939 BANDINGS							
Bands recovered	—	76	63	33	24	24	8
Bands not recovered.	228	152	89	56	32	8	0
Survival series[3]. . .	100	66.7	39.0	24.6	14.0	3.5	0
Survival rate[4]	—	66.7	58.6	62.9	57.1	25.0	0
Survival index, 62.7[5]							

[1] Data in this table were derived from table 34; included are totals obtained by adding the figures in each column of three 5-year periods, 1925–1939, years 1-2 through 6-7.
[2] Year of banding. Recoveries in this year not included in calculations in table.
[3] Survival series calculated as described in footnote 3, table 35.
[4] Survival rate calculated as described in footnote 4, table 35.
[5] Average of first 3 years of survival rate.

year of banding, are treated by 5-year groups. These data are shown graphically in fig. 79. Survival indices from these recovery data can be regarded as a fair approximation of average survival during at least the first 3 years of adult life after banding. However, the most nearly accurate survival index for 3 years of adult life (actually from at least 1½ to at least 4½ years of age) after banding, 60.7 per cent, is obtained from the complete recovery series, table 41 and fig. 75, curve II. A survival index for years of this study, an index calculated from trap returns rather than band recoveries and for the Horseshoe Lake flock, 48.03, is obtained from the data given in table 32. For purposes of comparison, survival indices obtained from the data discussed above are summarized in table 42. The converse of a survival index is a mortality index, that is, the average of mortality rates for 3 consecutive years. Mortality indices also are given in table 42.

Mortality data are available for only a few other game species. Leopold *et al.* (1943) have shown that in an unshot pheasant population a year class is reduced to zero in 5 years, and that the average annual mortality of a year class is about 70 per cent, a mortality rate that compares closely with that found for the Hungarian partridge and for the California quail by Emlen (1940). In contrast to these rates, annual mortality in many passerine birds appears to be between 50 and 55 per cent (Farner 1945).

Leopold *et al.* (1943) have stated that after a pheasant reaches its first winter its chance of survival apparently does not improve with age; that is, the survival rate is constant. The data presented by Buss (1946) do not agree with this conclusion. Because geese are longer lived than pheasants and acquire wariness and habits of survival value with age, it seems reasonable to assume that greater experience and learning with increased age in Canada geese would improve the individual's chance of survival. Band recoveries, as well as observations of living birds, have already shown that, insofar as shooting is concerned, juveniles have a greater mortality rate than adults. To discover whether mortality rates of Canada geese undergo change with increasing age after the first year of life, recoveries in table 41 have been plotted logarithmically, fig. 80. Losses prior to 1½ years of age are indicated in fig. 80 by a dotted line. The curve is "completed" only in order to obtain visual appreciation as to what its approximate shape might be if it were based on adequate and complete data for the entire life span. The curve suggests some improvement of survival with in-

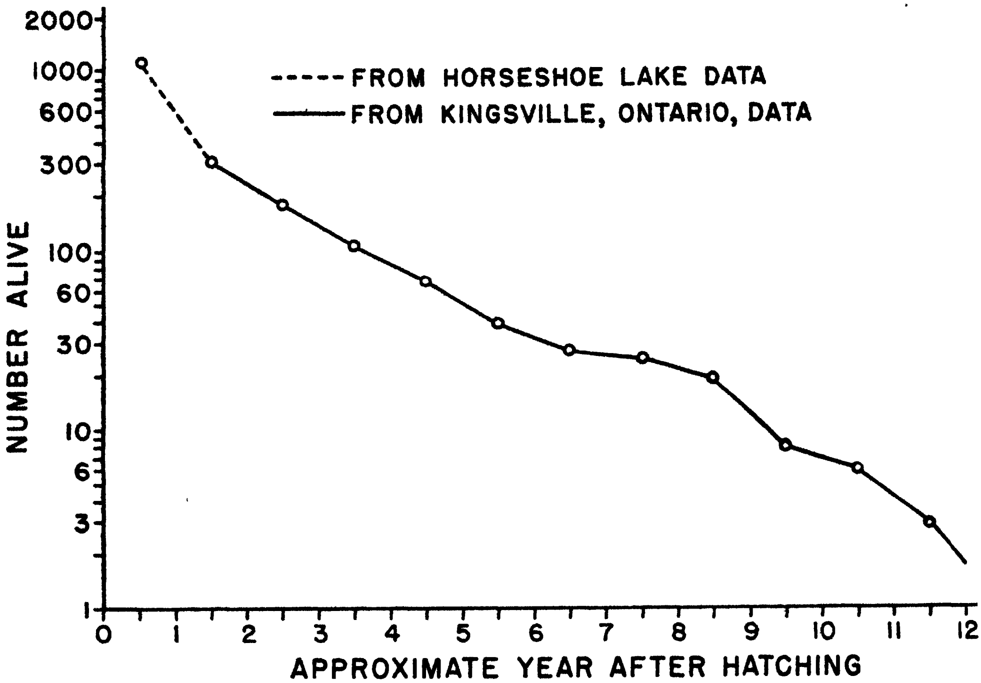

Fig. 80.—Approximate survival curve (semilogarithmic) for the Canada goose population of the Mississippi flyway, as indicated by age ratios and censuses of geese at Horseshoe Lake, 1940–1947, and by band recoveries from geese banded at Kingsville, Ontario, 1925–1932. Because geese banded at Kingsville were of unknown age at time of banding, the curve may be only a rough approximation of the actual survival curve.

creasing age after about the fifth or sixth year of life, but the evidence is not conclusive. The decreasing reliability of data 5 or 6 years after banding, the varying take by hunters from year to year, and the fact that the data represent, in the first place, geese of unknown ages tend to obscure the actual picture.

Longevity

Geese as a group are noted for being long lived, particularly in captivity;

Table 41.—Recoveries in the Mississippi River valley of bands from Canada geese banded at Kingsville, Ontario, in the autumn, 1925–1932. (Data from table 34.) This table differs from table 35 in that here the band recoveries from the year of banding are not included.

1925–1932 Bandings	Recoveries in Designated Year Following Banding											
	0-1[1]	1–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–10	10–11	11–12
Bands recovered . . .	—	126	72	36	29	11	3	6	11	2	3	3
Bands not recovered	302	176	104	68	39	28	25	19	8	6	3	0
Survival series[2].	100	58	34	23	13	9	8	6	2	2	1	0
Survival rate[3].	--	58	59	65	57	72	89	76	42	75	50	0
Survival index, 60.7[4]												

[1] Beginning of year following year of banding. The 302 in this column represents the total of the number of bands recovered after this time in the period included in the table.
[2] See third footnote to table 35. In the table above, recoveries in the year of banding are excluded, and the total number of recoveries considered is 302 instead of the 381 in table 35.
[3] See fourth footnote to table 35.
[4] Average of first 3 years of survival rate.

Table 42.—Survival indices of Canada geese banded at Kingsville, Ontario, in the autumn, and at the Horseshoe Lake Game Refuge.

BANDING SEASONS	AGE AT BANDING	BANDING STATION	SURVIVAL INDEX*	MORTALITY INDEX	KIND OF DATA USED	REFERENCE
1925–1932	All ages	Miner Sanctuary	60.7	39.1	Band recoveries	Table 41
1925–1929	All ages	Miner Sanctuary	47.6	52.4	Band recoveries	Table 40
1930–1934	All ages	Miner Sanctuary	59.5	40.5	Band recoveries	Table 40
1935–1939	All ages	Miner Sanctuary	62.7	37 3	Band recoveries	Table 40
1940–1947	All ages	Horseshoe Lake	48 0	52 0	Trap returns	Table 32
1940–1947	Juveniles	Horseshoe Lake	34.6	65.4	Trap returns and age ratios	Page 175

* These survival indices are an average of survival rates for years 1–2 through 3–4 and were derived as indicated in the "Reference" column of this table. They are slightly lower than if derived from a complete band-recovery series. The mortality index is derived by subtracting the survival index from 100.

Flower (1925) records that two Canada geese lived to be 29 years of age and a third 33 years. McAtee (1924) learned of one pair of Canada geese that were mated for 42 years and another pair for over 20 years. Wilfrid (1924) reported a gander he believed to be at least 40 years old at the time of the bird's death, and Leffingwell (1890) reported "as a matter of history" a captive bird that was killed when it was 80 years old. Doubtless there are other records in the literature that compare with these. Several instances of Canada geese, once used for decoys and later kept as pets, that attained ages of at least 20 years have been reported to the authors of this paper.

In the wild, few Canada geese approach these ages. The greatest age attained by a wild Canada goose, to our knowledge, is at least 22 years. This goose was banded at the Miner Sanctuary in the spring of 1923 and retrapped in the spring of 1932 and again in the spring of 1944. The life span of the average wild Canada goose after banding, however, proves to be only a few years, generally less than 3, but as Austin (1942) has pointed out, "It is of little importance biologically speaking how long members of a species live providing their life span is long enough for a generation to reach and maintain sexual maturity in order to duplicate the achievement of its predecessor."

In most instances, our data are inadequate to compute average longevities with accuracy. The complete recovery series, table 35, are of limited usefulness, since the geese involved were of unknown age when banded. These data are further complicated by the fact that the number of recoveries during the season of banding are not representative of usual first-year mortality. Average longevities calculated from data collected for the present study would be misleading. While average longevities derived from adequate data would serve ideally to compare the survival of individuals of different bandings, for the present study the survival indices shown in tables 29, 32, 40, 41, and 42 are useful and are more appropriate. From these indices and from other data, it seems obvious that few Mississippi Valley Canada geese live longer than 3 or 4 years after being banded.

An approximation of the longevity of juvenile geese banded at Horseshoe Lake in the years of this study may be obtained through computations beginning with the following formula:

$$S = \frac{f_1 y_1 + f_2 y_2 + f_3 y_3 \text{ etc.}}{N}$$

S stands for average survival after banding; f_1, f_2, etc. represent, for each age-class involved, the mortality frequency in each of successive years as computed from the survival series on page 174: 26.46, 11.53, 3.90, 3.73, 1.99 (mortality frequencies:* 73.54, 14.93, 7.63, 0.17, 1.74); y_1, y_2, etc. represent the number of years (1 through 5) following banding applicable to each mortality frequency; N represents the sum of the mortality frequencies. The mean death date of geese banded at Horseshoe Lake was about midway between mean banding dates.† Hence, the value calculated for S, 1.4 years, is corrected by subtracting 0.5 to give average survival after banding, 0.9 year.

As juveniles at Horseshoe Lake were about 0.5 year old when banded, this figure is then added to 0.9 to give the average longevity, 1.4 years. Thus, it might be said that the average banded juvenile goose and presumably the average juvenile in the unbanded Horseshoe Lake population in the years of this study did not live long enough to produce one brood of young.

DISCUSSION

It is axiomatic that the sound management of a wildlife species must in the last analysis rely on carefully gathered scientific data. Waterfowl studies usually concern migratory species for which it is difficult to secure adequate data from all parts of the range. The range of most waterfowl species is immense, and some populations shift their distribution within a flyway from year to year because of changing food, water, and weather conditions.

The aim of most broad studies of waterfowl species probably would be to gather

* Derived by subtraction: 100.00–26.46, 26.46–11.53, 11.53–3.90, etc.
† Mean banding date about December 1.

information that would allow management of the species concerned on a flyway basis, as recently suggested by Gabrielson (1944). Because Canada geese tend to exhibit a greater adherence to their ancestral range than do ducks, management by flyways for this species is more suitable than it would be for most other waterfowl. In fact, the fairly restricted range of the various Canada goose populations in eastern North America, as shown earlier, suggests the need for certain management measures for individual population ranges rather than for an entire flyway. Although additional information concerning the Mississippi Valley goose population is needed, enough is now available to permit this population to be managed primarily as individual population units.

Status

In 1946, 14 states of the Mississippi flyway (Michigan, Wisconsin, Minnesota, Ohio, Indiana, Illinois, Iowa, Kentucky, Tennessee, Missouri, Mississippi, Alabama, Arkansas, and Louisiana) were closed to the hunting of Canada geese. The closed season of an entire flyway was the first of its kind in the history of this species of waterfowl. The only similar actions ever taken were those closing the shooting seasons on snow geese and brant in the Atlantic Coast states. Snow-goose hunting has been prohibited there since 1931, and brant hunting for more than half of the years since 1933.

The closed season on Canada geese in the Mississippi flyway in 1946 was believed necessary for a number of reasons: an alarming decrease in the number of these geese in the Mississippi flyway from 1940 to 1945, as indicated by January inventory data; markedly increased kills beginning in 1939, particularly in the region of Horseshoe Lake; a disproportionate kill of juvenile birds and an apparent decreased productivity in 1945, as indicated by research at Horseshoe Lake.

The peak number of geese at Horseshoe Lake dropped from about 50,000 in 1943–44 to 26,000 in 1945–46. That this decrease represented a real decrease in the flyway population and was not due to bypassing of the area by flocks is shown not only by flyway censuses but by band-recovery records. These records indicate that since 1932 many of the geese that formerly used the Mississippi River from Cairo, Illinois, to Baton Rouge, Louisiana, have concentrated in a much smaller area centering on Horseshoe Lake, probably because of the refuge there and the large amount of grain available to the geese.

Known bags and careful estimates of kills indicate that, in the years just previous to 1946, an average of about 20 per cent of the Canada goose population wintering at Horseshoe Lake was bagged annually, and that the total annual kill in the area averaged about 27 per cent of the population. In view of the fairly low productivity of the Canada goose, it is obvious that a reasonable kill in this area was greatly exceeded. Population declines at Horseshoe Lake and in the Mississippi flyway as a whole showed that flock mortality from all causes combined had been excessive, and, as hunting losses are one type of mortality that can be controlled, it was evident that closing the entire flyway to shooting was the most effective management measure that could have been employed.

Evidence of increased shooting pressure on Canada geese in years just previous to 1946 is illustrated by the survival curves, fig. 77, representing data computed from band recoveries from geese banded at the Jack Miner Bird Sanctuary, Kingsville, Ontario. These data show that the annual survival rate for that portion of the population migrating through the Kingsville area was lower in the 5 years beginning in the fall of 1940 than in any comparable period in the previous 15 years, fig. 77. Chiefly responsible for this lower survival rate were the heavy kills made at Horseshoe Lake; band recoveries show that the survival rate of the Horseshoe Lake flock was well below the average for the entire Mississippi Valley population. In fact, the survival series for the Horseshoe Lake flock was lower during the period 1940–1945 than it was in the entire Mississippi Valley population in the years in which baiting and the use of live decoys were permitted, tables 10, 37, and 38.

Moffitt (1935) was concerned over the future of a flock nesting in California when he realized an 11.5 per cent first-season recovery rate from his bandings. Unpublished studies by Cecil S. Williams

of the United States Fish and Wildlife Service at the Bear River marshes, Utah, indicate that the Great Basin population he dealt with could show a first-year band-recovery rate of 16 per cent and a total band-recovery rate of 25 per cent and still increase. Total recoveries from Horseshoe Lake bandings were at only about half the rate of total recoveries reported for the Great Basin, but other data indicated a heavy kill rate and a decline in the Horseshoe Lake population in the years just previous to 1946. While Williams' data establish the fact that the Canada goose could withstand heavy shooting losses in the Great Basin, conditions vary too widely in the various flyways to predict on the basis of data from one area (Utah) what the conditions are in another (Horseshoe Lake).

Interpolating from fig. 74, curve I, which is based on a survival series obtained for the Horseshoe Lake flock, it appears that only about 16 per cent of the juveniles reaching Horseshoe Lake during the period of field work for this study lived long enough to see a brood of their young on the wing.

When a major portion of the annual kill of a Canada goose flock is at the expense of one age group, data on the total number of birds bagged do not reveal the true impact of the kill upon the total population. At Horseshoe Lake the juveniles made up the major part of the kill in the period covered by this study, tables 43 and 44. In the autumn of 1943, the juveniles made up 56 per cent of the population, while 91 per cent of the hunter's bag consisted of juveniles. In that year, 37 per cent of the juvenile population at Horseshoe Lake was bagged. The following year, the 1943 generation (then yearlings) comprised only about 29 per cent of the total adult birds. The effect of this differential kill is also shown by trap-age ratios of banded survivors in later years. In table 43, returns for the years 1943–1947 of geese banded during the autumn and winter season previous to

Table 43.—Juvenile-adult ratios of Canada geese at Horseshoe Lake, 1942–43 through 1946–47, arranged to show the effect of a differential kill on survival. (See table 23.)

Season	Juveniles Per 100 Adults Banded	Juveniles Per 100 Adults in Bag	Number Returning to Traps 1 Year Later			
			Age Class	Number	Per Cent of Original Banding	Yearlings Per 100 Adults
1942–43..	153	259	Juvenile	67	10 82	137
			Adult	32	7.92	
1943–44.	145	1,053*	Juvenile	87	6 31	56
			Adult	107	11 26	
1944–45..	246	942	Juvenile	106	17.46	173
			Adult	25	10 08	
1945–46..	172	410	Juvenile	39	19 90	87
			Adult	26	22.81	

* Although this figure is based on a smaller sample than in most other years, field observations and data collected subsequently indicate that it is a close approximation of the actual kill ratio.

Table 44.—Calculated kill of juvenile Canada geese at Horseshoe Lake, 1942–43 through 1945–46, exclusive of crippling losses.

Season	Number of Juveniles in Flock (See Table 27)	Total Kill, All Ages	Per Cent of Bag Made up of Juveniles	Calculated Number of Juveniles in Bag	Per Cent of Total Juveniles in Flocks Bagged by Hunters Near Horseshoe Lake
1942–43........	32,450	6,529	72.1	4,707	14.5
1943–44........	29,680	12,062	91.3	11,013	37.1
1944–45........	22,316	7,807	90.4	7,058	31.6
1945–46........	10,534	5,244	80.4	4,216	40.0

each of these years are given. In the autumn of 1942, when only 2.59 juveniles were shot for every adult, the survival rate of juveniles was evidently favorable to this age class as 10.82 per cent of the total banded juveniles returned to the traps in the following year as compared with 7.92 per cent of the adults, or a ratio of 1.37 juveniles to 1.0 adult.

In contrast to this survival picture is the highly differential kill that occurred in 1943 when the ratio of juveniles to adults shot at the hunting clubs surrounding the refuge was 10.53 to 1.0, table 43. The next year the return to the traps was only 0.56 juvenile (then yearling) to 1 adult. Despite the fact that juveniles bore the brunt of the kill in 1944, table 44, the net loss to the juvenile segment of the population was somewhat less, with the result that the ratio of juvenile (then yearling) to adult returns in the traps a year later, in 1945–46, was 1.73 to 1.0, table 43.

A relatively high kill of juveniles coupled with a year in which productivity is low is almost certain to place a goose population in a hazardous position. Banding at Horseshoe Lake indicated a decrease in productivity in 1945 from the productivity in 1944, table 43. The relatively small number of young produced in 1945 may have been related in part to the cold weather in the spring of that year; the productivity of mallards also was greatly reduced in that year. A depressive effect on the intensity of mating or on nesting success in many species of birds has been attributed to late and cold springs. The following species said to be affected thus might be cited: Canada goose (Johnson 1947); arctic tern (Lack 1933); eiders and loons (Bird & Bird 1940); moor hen (Huxley 1932); and house wren (Kendeigh 1942).

However, it is conceivable that part of the decrease in productivity in 1945 may have been apparent rather than real. Undoubtedly juveniles contribute a larger proportion of the kill during migration than do the adults, but the extent to which shooting north of the Horseshoe Lake Game Refuge is selective of juveniles is not known. Because the kill between the refuge and the Canadian border in 1945 was much larger than usual, the age ratios in the southward-bound flocks may have been significantly altered by shooting in that particular year.

The subject of cycles in waterfowl is still largely an unexplored field. It does not appear to be known generally that, in the arctic, geese, ducks, and loons may be subject to nonbreeding years (Manniche 1910, Bertram, Lack, & Roberts 1934, Bird & Bird 1940). Keith (1937) writes, ". . . . 1936 was a 'non-breeding year' [in Northeast Land, Spitzbergen Archipelago] when large numbers of Ducks and Geese failed to nest; and in other parts of the Arctic it had always before been found that the Divers [loons] were also affected by these years and that of them too only a small proportion were breeding." As nonbreeding of waterfowl has been reported only from high arctic areas, it is debatable whether the Canada goose populations dealt with here are similarly affected.

At present, low productivity in blue geese and snow geese appears to be confined to summers in which inclement weather directly affects the success of nesting (Soper 1930). In the opinion of Berry (1939), "climate is of the utmost importance in limiting the survival rate of goslings on the northern breeding grounds."

A year of low productivity in Canada geese should be of particular concern to the administrators who seek to influence the kill by hunting regulations, for the reason that the young birds bear a double responsibility. Being more vulnerable to shooting than the adults, they must contribute a disproportionate share of the kill, and, secondly, they must survive in sufficient numbers to help reproduce an equivalent of the annual loss in the breeding population. Even in a year when the production of young was not significantly low, 1943, shooting losses in the Horseshoe Lake area were so severe and so greatly at the expense of the juveniles that only a small proportion of this generation survived to reach the minimum breeding age of 2 years.

Management

What can be done to insure the future of the Mississippi Valley geese? Until recent years, two prime measures for con-

serving waterfowl, hunting regulations and refuges, have been fairly successfully used in the management of this group. As applied to the population of geese dealt with in this report, it is apparent that these measures were not very effective in the period of field work.

In Canada.—Several factors minimize the need for any immediate change in measures relating to the Mississippi Valley population while in Canada. The relatively inaccessible nature of the Canadian breeding grounds insures adequate protection for the flock during the actual breeding season.

The kill in Canada is not excessive, and a reduction of the early spring kill on the breeding grounds would be difficult because much of this kill is virtually necessary for the survival of native Indians. Furthermore, our kill and population data indicate that the annual rate of kill (the percentage of birds taken from the returning population in the spring) by the Indians is relatively constant. In general, only when there is an actual increase in the Canada goose population does a significant increase in the number of these geese bagged by Indians occur. This relatively constant relationship is evidence that the goose kill by natives cannot be considered the direct cause of any considerable population decrease that might be reported in the United States from any of the annual January inventories.

In the United States.—In 1944 and 1945, when season bag limits were imposed for Alexander County, Illinois, table 10, it was a relatively easy matter to limit the kill of geese in the Horseshoe Lake area to approximately the predetermined figures. The facility with which the day-to-day kill can be tallied is perhaps the outstanding advantage of encouraging a portion of the flock to utilize the refuge there. The season bag limit in the above instances was determined by the trend of the population in prior years, but, to be fully effective, management should anticipate future trends based upon the current composition of the population. With the data at hand on the Canada

Table 45.—Calculated losses and reproductive gains for the Horseshoe Lake Canada goose flock between the autumn of 1944, and the autumn of 1945.[1]

Classification	Total Added (Young Produced)	Total Lost	Balance (Total Surviving)
Flock arriving at Horseshoe Lake in the autumn of 1944 (includes 6,885 yearling and older females)			40,500
Number lost from hunting at Horseshoe Lake (includes 525 yearling and adult females)		10,550	
Maximum number flying north in spring (includes 6,360 females older than 1½ years of age)			29,950
Kill by Indians in the Hudson-James Bay area[2] (includes 277 females 2 or more years of age)[3]		2,100	
Natural losses for year at 18 per cent of 40,500 (includes estimated 1,000 adult females)[4]		7,290	
Total yearlings and adults alive after breeding season (includes 5,083 adult females)			20,560
Number of young brought to flying stage (3 per adult female)	15,189		
Approximate total at start of autumn migration			35,749
Kill by hunters in flyway north of Horseshoe Lake (at 6 per cent of southward flight)[5]		2,135	
Number calculated to arrive at Horseshoe Lake in 1945			33,614
Actual number to arrive at Horseshoe Lake in 1945 (inventory figure, January, 1946, plus total hunting loss in area)			29,100

[1] In most cases calculations are based on actual data, in others on estimates.
[2] Proportional share of total kill suffered by the Horseshoe Lake flock.
[3] Vulnerability of yearlings 2.8 times that of older geese; kill of adult females should not exceed 13 per cent of the total loss.
[4] The loss rate from natural causes tends to be inversely related to the losses from hunting.
[5] The kill of Canada geese between the Canadian border and Horseshoe Lake was particularly heavy in 1945; hence, the actual kill for that area probably exceeded 6 per cent of the southward flight. For reasons explained in footnote on page 150, the actual kill rate in this area in most years is probably closer to 8 or 10 per cent of the southward flight.

goose in the Mississippi River valley, it is possible to arrive at a practical estimate of the maximum kill that can be tolerated.

A method by which management of the Mississippi Valley population might proceed is best illustrated by a concrete example, table 45. Similar calculations based on sex and age ratios from trapping, and made by the authors in the spring of 1945, forecast a decreased population for the autumn of 1945. Censuses during the autumn and the inventory of January, 1946, proved the accuracy of this prediction.

Since the autumn flight in any year depends to a large extent on the production of young in the spring of that year, it is necessary to know the approximate number of breeding females and to have some measure of the nesting success on the breeding grounds to predict the autumn flock population with reasonable accuracy. Inventory on the breeding grounds would be difficult because of the nature of the terrain, but the use of planes would aid tremendously in such work. For the present, and until more data are available, the average productivity of the population might be calculated on the basis of three young (brought to flying stage) per adult female.

If the flock population has been fairly stable for several years or is on the increase, a bag of 10 per cent of the number wintering in the Horseshoe Lake area might prove to be within the limits of what the flock could stand without decreasing in size. Even this kill might be too high if kills north of Horseshoe Lake were unusually large in a given autumn, if nesting success was low the previous spring, or if sex and age ratios were seriously unbalanced. When the population is very low, the kill of a single bird constitutes overshooting.

A reduction in the crippling loss would allow the season bag limit in the Horseshoe Lake area to be increased. The number of geese crippled and lost to hunters each year in the area is needlessly high. An estimate of cripples not retrieved and soon dying is placed at 30 per cent of the number of geese bagged. Certain administrative measures can be taken to reduce the per cent of cripples not retrieved. For instance, adequate spacing of pits to reduce competition among hunters would materially aid in reducing crippling losses. But a large share of the responsibility will rest with the hunter himself, who must restrain the natural desire to "give a high one a ride." Some hunters hope to bag geese with greater ease by using magnum shotguns. However, it is open to debate whether more geese are bagged than crippled by such guns because of the out-of-range shooting their possession encourages. At least in one instance a 10-gauge magnum shotgun is known to have failed to live up to its owner's expectation; a tally of empty casings from this shotgun in one pit, presumably fired to bag the limit of two geese, was 22, as against the average of 9 cartridge casings per hunter for all pits inspected.

It is clear from tables 15 and 10, showing kill and hunting regulations in the Horseshoe Lake area, that hunting restrictions were not always successful in reducing the kill to the desired extent, but, if various measures instituted to lower the annual kill had not been taken, it is probable that a large proportion of the Canada geese using the Horseshoe Lake area would have been shot by the end of 1945.

Under normal conditions, the duration of the hunting season can be expected to show a fairly direct relationship to the kill, but, when the natural wariness of the geese has been reduced, as at Horseshoe Lake, the length of the hunting season may show no correlation with the kill, figs. 52 and 53.

Pirnie (1939) has emphasized that "Changing habits of these birds [Canada geese] may create new hazards for them and require even more stringent regulations." The behavior of the Horseshoe Lake flock in recent years and its relation to shooting has already been discussed, but it should again be emphasized that restrictions alone cannot be expected to safeguard it.

Refuges form an important part of our system for the preservation of waterfowl. Whether or not any individual refuge proves of value will depend to a certain extent upon its management and also upon its size. Leopold (1931) stated the chief problem in regard to the Horseshoe Lake Game Refuge soon after this refuge was

created. "The question of whether public refuges should be surrounded by public shooting grounds is frequently debated. Horseshoe Lake in Alexander County, Illinois, is a good place to study the question."

Twelve years after this statement was published the answer was forcibly given by Gabrielson (1943). "Because of its [Horseshoe Lake Game Refuge] attractiveness to Canada geese, small size, lack of food, and peculiar relation to surrounding lands, it has become a slaughter pen rather than a refuge."

The breakdown in wariness that occurred was perhaps more serious to the future of the Horseshoe Lake flock than the reduction in its size. The steps believed necessary to re-establish wildness in the flock were as follows: (1) Establish refuge areas on the nearby islands and bars of the Mississippi River or on lands adjacent to the river; (2) disperse the geese from Horseshoe Lake to these bars and islands; that is, drive them back to their original habitat; (3) insofar as possible, reduce contact between human beings (both the public and refuge personnel) and the geese.

In the past years in which the geese used both the river bars and the refuge, they retained their natural wildness; coincident with their almost complete dependence on the refuge for food and grit, they lost much of their wildness. The river refuge might act as a final sanctuary for the flock should it be disturbed for any reason at Horseshoe Lake, and ideally it should contain the bulk of the flock at most times.

Canada geese will feed by moonlight, at daybreak, or at dusk, if they are disturbed while feeding during the day. This fact may offer a partial solution to the Horseshoe Lake problem. If the geese were permitted to feed at the Horseshoe Lake Game Refuge only during the hours of dawn and dusk, the re-establishment of wildness might occur and with it a reduction in the rate of kill. We have a precedent for such a course of action in the operation of the Miner Sanctuary, where the geese feed only in the early morning hours and at dusk, spending the remainder of their time roosting out on Lake Erie.

State regulations just previous to 1946 prohibited the placing of shooting pits within 75 to 150 yards of the boundary of the Horseshoe Lake Game Refuge. This buffer zone, which was intended to allow the geese to attain safe heights before reaching the shooting pits and blinds was unquestionably insufficient, since many of the geese leaving the refuge encountered shot pellets 75 yards away from the first line of pits. Although the Miner Sanctuary consists of only 400 acres and supports an even greater density of geese than is ever experienced at Horseshoe Lake, excessive kills have not occurred near this Canadian refuge in late years. Responsible in part for the small kills reported in the vicinity of the Miner Sanctuary is a buffer zone that surrounds the ponds and feeding grounds for a distance of a mile. When geese leave the refuge, they have sufficient space in which to gain altitude before passing over the shooting grounds.

The present food resources of the Horseshoe Lake Game Refuge are insufficient to winter more than 20,000 geese, and probably only 15,000 can be accommodated to best advantage. When the corn crop and wheat browse on the refuge are exhausted, and sometimes before this occurs, the flock feeds on unharvested and waste grain and on the green plants of winter wheat in fields of the surrounding countryside—occasionally at a considerable loss to farmers who do not rent their fields to hunters. Unless the flock is broken up and scattered to other areas in the flyway, the local food conditions must be improved, either through the acquisition of more land or by an artificial feeding program. The artificial program is wholly undesirable unless it is carried out on an isolated tract of land. On the other hand, the development of a river refuge would certainly increase the flock's usage of natural foods—the grasses, sedges, and switch willows on which the geese formerly fed.

The present size of the Horseshoe Lake Game Refuge is woefully inadequate for the geese using the area, as experiences there and elsewhere have demonstrated. A program involving purchase of additional lands has been planned by the State Department of Conservation for several years, but has been blocked by the inflated prices of lands in the area—inflated

prices resulting in part from the commercialization of goose hunting.

Census data showed that, between 1942 and 1945, the Canada goose in the Mississippi River valley suffered a marked decline in population. Kill records showed an increase in the annual bag beginning in 1939, and banding data revealed a concurrent decrease in goose survival for the same period. The conclusion must be reached that the Mississippi Valley Canada goose population was shot too heavily in that period and that stringent protection was necessary to insure perpetuation of this population.

PRESENT SITUATION

The time lapse between completion of the field work reported here and publication of this article has been sufficient to permit an evaluation of some of the measures recently taken to assure the future of the Canada goose population of the Mississippi River valley. The decision to close the valley to Canada goose hunting in 1946 was based partly on evidence gained from banding that the geese wintering at the Horseshoe Lake Game Refuge were suffering unprecedented losses from hunting and were being killed at a rate far greater than the flock could stand and still maintain its numbers. In addition was the evidence from annual inventories that the flyway population was at an alarmingly low level.

In 1947, the shooting of Canada geese was again permitted in the Mississippi River valley, but on a restricted scale. The season opened on November 4 and closed on December 3. The bag limit was reduced to one bird per day and the possession limit was also one bird. To insure against a return of heavy kills in the Horseshoe Lake region, an area in the region totaling approximately 15,000 acres was declared closed by proclamation of the President of the United States with the joint support of the Governor of Illinois. By this action, a buffer area, roughly 2 miles in depth, was created around the Horseshoe Lake Game Refuge. In 1948, the hunting season opened on October 29 and closed November 27. During this 30-day season, hunters were permitted to bag two Canada geese per day and were allowed a possession limit of two birds.

The response by the geese to greater protection has been most heartening, their comeback demonstrating both that the kill by hunters in the United States was a major suppressive factor on the population, and that this population, given opportunity, possesses strong recuperative powers. With a capital investment of 49,000* birds in the Mississippi flyway in the winter of 1945–46, interest in the form of 1946 reproduction was reinvested as capital gain by virtue of the closed season. Inventory in January, 1947, revealed a capital gain of approximately 25 per cent, table 7. This recovery by an almost bankrupt population so encouraged the committee on regulations that a dividend, in the form of an open season, was declared permissible for the autumn of 1947 and again for the autumn of 1948. The dividend in the Horseshoe Lake area in 1947 was 1,644 geese bagged by hunters; in 1948 it was 2,587 geese bagged by hunters. In addition to this number, other geese, estimated at 2,000, were shot illegally within the buffer area closed to hunting outside the refuge. We do not have the data at hand to show what the profits were to hunters in other states in the flyway, but that the goose business could afford the dividends is shown by the recent summary of capital stock given in table 46.

The recovery made by the Mississippi Valley population has not gone unnoticed by the Indians who trap and hunt on the breeding grounds before the actual commencement of nesting. In August, 1949, the senior author learned at Fort Albany that the Indians there had observed more geese in the spring of 1949 than at any other time in recent years. Similarly, questionnaire answers received from Raymond M. Alaine of Weenusk, September 21, 1949, stated that the Indians at that post had not seen as many geese in any other years of the last 10 as they did in the fall of 1948.

Future management of the Horseshoe Lake flock by the United States Fish and

* This figure includes geese from western Louisiana, birds that possibly belong to the Eastern Prairie population and that should not be included in the Mississippi Valley population. Hence, it exaggerates the size of the Mississippi Valley population for 1945-46.

Table 46.—Population of Canada geese in the Mississippi River valley in 1947–48 and 1948–49, from January inventory, except as noted.

State or Other Area	Season 1947–48	Season 1948–49
Michigan	5,000	6,000
Wisconsin	4,200	4,760
Indiana	1,679	7,449
Illinois (total)	57,205	90,414
Mason County	—	960
Horseshoe Lake	—	46,000
Craborchard Lake, Williamson County	—	30,000
Lyerly Lake, Union County	—	12,450
Miscellaneous areas	—	1,004
Kentucky	1,500	7,200
Mississippi	5,500	7,250
Tennessee	2,500	9,450
Arkansas	9,000	12,000
Missouri	—	5,000*
Louisiana	10,000	10,000
Total	*96,584*	*159,523*

* Most of these geese were a part of the flock wintering in the Horseshoe Lake area.

Wildlife Service and the Illinois Department of Conservation envisions the breaking up of this concentration and dividing it among four other refuge areas: Craborchard National Wildlife Refuge, Williamson County, Illinois; Lyerly Lake State Refuge and Public Shooting Grounds, Union County, Illinois; the Mingo National Wildlife Refuge, Missouri; and the Kentucky Woodlands National Wildlife Refuge bordering the Tennessee River south of Paducah, Kentucky. To implement the dispersal of geese from Horseshoe Lake, planes, guns, bombs and various other pyrotechnic devices were used to frighten the geese in 1947, 1948, and 1949. That this dispersal program is meeting with success is evident from the data presented in table 46. Provided with these other areas, an ample food supply, and adequate legal protection, the Canada goose population in the Mississippi valley faces a future that seems assured for some years to come.

SUMMARY

1. The Horseshoe Lake Wildlife Refuge, located at the southern tip of Illinois near Cairo and created in 1927 by the Illinois Department of Conservation, totals approximately 3,700 acres.

2. Soon after the refuge was formed, increasing numbers of Canada geese, decoyed from their traditional wintering grounds along the Mississippi River by the food and protection offered, began to use this refuge. In most recent winters the refuge has attracted about 50 per cent of the Mississippi Valley Canada goose population. With the increase in the size of the flock at the refuge, there was a loss of wariness on the part of the geese, accompanied by a tremendous increase in the annual kill.

3. In the eastern half of the United States there are two subspecies of Canada geese. The easternmost race, *Branta canadensis canadensis,* comprises the geese of the North Atlantic population. The other race, *Branta canadensis interior,* which breeds principally west, south, and east of James and Hudson bays, is composed of four subgroups, each of which constitutes a separate flyway population. The four subgroups are as follows: the South Atlantic, the Southeast, the Mississippi Valley, and the Eastern Prairie.

4. The main breeding range of the Mississippi Valley geese is believed to lie within the western limits of the Paleozoic Basin west of James Bay and south of Hudson Bay. The majority of the nesting geese of this population are found in relatively restricted areas of the vast, lowlying, muskeg-covered plain of the region.

5. Aerial observations revealed that the type of muskeg attracting the greatest numbers of geese is one that is studded with potholes of a few acres to about 30 acres in size, so closely grouped that often only a narrow strip of land or floating vegetation separates one from another.

6. Most nesting pairs of Mississippi Valley geese are concentrated in production centers, but, as most of these production centers are of considerable size, scattered nesting, with one or two pairs to a small lake, seems to be the rule west of James Bay and south of Hudson Bay.

7. Before the southward migration of Mississippi Valley geese begins, about August 15, some family groups and small flocks begin a series of local flights, the termini of which are favored feeding grounds along the west coast of James Bay and the south coast of Hudson Bay, the tundra of Cape Henrietta Maria and the coastal marsh of Akimiski Island. The

tundra of Cape Henrietta Maria is favored because of the quantity of berries usually available there.

8. At least half of the Mississippi Valley geese do not fly to the coastal areas before migrating, but leave directly from their muskeg breeding grounds and strike south on a broad front. These are believed to be the geese that cross the Canadian border into eastern Minnesota and the upper peninsula of Michigan.

9. While probably at least a few Canada geese in migration pass over most areas of the Mississippi flyway each year, band recoveries and observations indicate that the following routes are most frequently used: from the Miner Sanctuary to Horseshoe Lake via Lake St. Mary, the Wabash and Ohio rivers; from Saginaw Bay southwest across the lower peninsula of Michigan to the W. K. Kellogg Bird Sanctuary area and the lower Kalamazoo River; southward along both shores of Lake Michigan. Migration through Wisconsin is principally in the eastern half of the state. The west shore of Lake Michigan is followed by appreciable numbers of geese. Two other routes appear to be favored: (1) the valley of the Wisconsin River; (2) Green Bay south to Lake Winnebago, the flight probably splitting south of Lake Winnebago, one section going to the Lake Geneva area, the other following the Rock River valley. Migration through Illinois appears to take place on a fairly broad front although the Illinois River valley is particularly favored.

10. Band-recovery data indicate that turnover in the population wintering at Horseshoe Lake is negligible. Geese that are decoyed into this refuge usually remain there for the rest of the season.

11. A portion of the Mississippi Valley geese migrating through the Kingsville, Ontario, region do not visit the Horseshoe Lake Refuge but by-pass it to the east, probably via the Tennessee River, and winter on the lower Mississippi.

12. The northward migration in spring is more nearly on a directly north and south axis than routes taken in the autumn. The flights of Mississippi Valley geese that stop at the Miner Sanctuary in the autumn do not reappear there in the spring in appreciable numbers; presumably they return to the breeding grounds by a more westerly route. The spring flights through the Kingsville region are comprised chiefly of South Atlantic geese.

13. Autumn migration of Mississippi Valley geese occurs over a 3-month period; the last geese to reach Horseshoe Lake in appreciable numbers arrive in early December. Much of the late flight represents the exodus of geese from the Miner Sanctuary when feeding there is curtailed.

14. The southward movement of the Canada geese from the breeding grounds may be compared with a segment of the concentric waves produced by an object striking the surface of a body of water. Geese that leave the breeding grounds earliest are believed to winter in the most southerly areas of the flyway. Those that leave the breeding grounds last are believed to winter in the most northerly areas of the wintering grounds.

15. In spring, the first flocks generally arrive on the breeding grounds between April 15 and 25, 2 to 3 weeks before the breakup of the major rivers.

16. Winter concentrations of Canada geese occur in the region of Kingsville, Ontario, westward to southern Wisconsin, and south to the Gulf Coast.

17. Although the Canada goose is widely reputed to be an extremely wary and difficult species to hunt, the behavior of this species at Horseshoe Lake in recent years has contradicted this reputation. Believed responsible for the high vulnerability of Canada geese to shooting in the vicinity of this refuge are the psychologically pacifying effect of large numbers of geese at rest on a relatively small area; the frequent sight of man in a benign role; and the decreased mobility of the flock when food is abundant on the refuge, as well as on adjacent hunting areas.

18. Goose hunting in Illinois, once a sport carried out in widely scattered areas of the state, is now confined largely to the Illinois River valley and the Horseshoe Lake region.

19. In the period 1944 through 1947, the kill of Canada geese of the Mississippi flyway by Canadian Indians is computed to have been between 4,000 and 5,500 or from about 8 to 10 per cent of the number of birds that attained the breeding grounds in the spring. Approxi-

mately 25 per cent of the total number of Mississippi Valley Canada geese bagged in recent years have been taken by Indians.

20. The waterfowl kill made by the Indians of the James Bay region is sometimes vital to actual survival of the Indians. Blue geese and snow geese greatly outrank the Canada goose in importance during the fall hunt along the coastal marshes; in spring, when the Indians are trapping inland along the rivers and creeks, the principal kill of Canada geese occurs, while relatively few blue geese and snow geese are shot at this time.

21. The restocking of beaver in some areas of the Canadian goose breeding range is beginning to relieve some of the hunting pressure on Canada geese.

22. The kill in the Horseshoe Lake area first began greatly to exceed what the flock could stand in 1939 when a kill of 17,300 geese was made. The average number of geese bagged in the Horseshoe Lake area in the autumns of 1939 through 1945 was about 9,800. In the autumns of 1943, 1944, and 1945 the bag amounted to 23, 19, and 18 per cent, respectively, of the number of geese that arrived at the refuge in those years.

23. The annual bag of geese in Illinois in areas other than Horseshoe Lake averaged approximately 1,100 birds in the period covered by this report.

24. Next to Illinois, Michigan made the largest kills of Mississippi Valley geese, 1938–1944; the annual bag was probably between 1,000 and 3,000 birds.

25. Bag inspections at hunting clubs near Horseshoe Lake showed that juvenile geese made up a high percentage of the total kill, 1940–1945. In 1943, juveniles were about eight times as vulnerable to hunting as adults.

26. Crippling losses among geese at Horseshoe Lake in recent years are estimated to have been equivalent to about 30 per cent of the annual bag.

27. Causes of death among Canada geese at Horseshoe Lake include lead poisoning (from ingestion of lead pellets), bound crop (perhaps a result of lead poisoning), tracheitis, and aspergillosis.

28. Sex ratios obtained from trapping geese at Horseshoe Lake show that there were slight, but statistically significant, larger numbers of males than of females in the juvenile and adult age classes, 1940–1946. Bag-inspection figures showed no significant preponderance of either sex in either age class, 1940–1945.

29. Nesting success of geese is not appreciably affected by the Canadian Indians, since the bulk of the kill is made in early spring before geese have begun to nest. Foxes may have a slight effect on nesting success when their other prey species, which appear to be cyclic, are low in numbers.

30. In 7 years of trapping and bag inspection at Horseshoe Lake, the age ratios obtained varied from 57 to 204 juveniles per 100 older geese. In 1944–45, trapping indicated that 55 per cent of the population consisted of juveniles. Trapping in the following year indicated that the proportion of juveniles had dropped to 36 per cent.

31. Average flock size, computed from frequency counts of flocks of nine or fewer geese on the wintering grounds, may provide a quick means of appraising breeding success of geese in the previous spring.

32. Low survival of Canada geese banded at the Jack Miner Bird Sanctuary, 1940–1944, is believed to have been brought about chiefly by the tremendous increase in the kills made in the region of Horseshoe Lake.

33. Mortality data calculated from trapping and band-recovery figures show that the Horseshoe Lake flock had a lower survival rate during the period of this study than did comparable banding classes from the Miner Sanctuary.

34. Mortality indices, the average of mortality rates for three years after banding, provide a possible basis for comparing mortality between different populations and banding classes of geese.

35. Survival data for the Horseshoe Lake flock, 1941–1945, indicate that the average juvenile did not live long enough to produce a brood of young.

36. In 1946, no open hunting season on Canada geese was permitted in the Mississippi River valley. In 1947, shooting on a restricted scale was permitted.

37. Increased protection of the Mississippi Valley Canada geese plus certain other management practices resulted in an appreciable gain in the population by the fall and winter of 1948–49.

APPENDIX A

THE SOUTHEAST POPULATION

ONE of the important findings from our study of the Jack Miner banding data, as they relate to the Horseshoe Lake problems, is the existence of a distinct and heretofore unrecognized group of Canada geese that winter in the inland areas of Virginia, North Carolina, South Carolina, Georgia, and Alabama and on the Gulf Coast of Florida. Because management of the Mississippi Valley goose population should be guided to some extent by a knowledge of neighboring goose populations, it seems desirable to include in this paper a brief summary of the breeding and wintering ranges, as well as the migration paths, of the Canada geese of the newly defined group, to which we have given the name Southeast population.

Breeding Range

To date there have been no recoveries of Horseshoe Lake goose bands in the Moose River district of James Bay or at the extreme south end of this bay, while fair numbers of bands have been recovered in that region from geese banded at the Jack Miner Bird Sanctuary near Kingsville, Ontario. Large numbers of Miner bands from the autumn flight have been recovered in the inland portions of the southeastern states. It appears from band recoveries that the Southeast geese nest from the country drained by the Moose River, south and east to the Nottaway or Rupert river country. In an area north of the Moose River, the breeding grounds of these geese merge with those of the Mississippi Valley population; east of the Nottaway River, or Rupert River, they merge with the nesting grounds of the South Atlantic geese, most of which migrate through the Kingsville area only in spring.

Census data on the flyway of the Southeast population are meager. Because the scattered flocks were not recognized as components of this distinct population, their significance was lost in the usual method of lumping census figures by states. Population figures presented below are from three sources: letters to Jack Miner from local sportsmen or officials; personal conversation with W. P. Baldwin, Jr., United States Fish and Wildlife Service biologist, stationed at Port Wentworth, Georgia; and records in the files of the Division of Refuges, United States Fish and Wildlife Service. Following is a summary of the wintering grounds of the Southeast population, as indicated by band recoveries and other data.

Migration Routes

In the autumn migration, the range of the Southeast population overlaps that of the Mississippi Valley population between James Bay and the Miner Sanctuary. At the latter point, however, band recoveries indicate that the birds of the Southeast population split off from the Mississippi Valley population and fan out south and southeast over a number of courses. The paucity of recoveries between the Miner Sanctuary and the eastern and southern slopes of the Appalachian Mountains suggests that most of the geese of the Southeast population make few stops en route to their wintering quarters.

The routes taken by these geese on their northward migration are probably mainly to the west of their autumn migration paths, as band recoveries show that comparatively few of the birds retrace their autumn flight through the Kingsville, Ontario, region.

Winter Concentrations

The wintering grounds of the geese of the Southeast population lie mainly in the Piedmont region east and south of the Appalachian Mountains, and in some parts of the coastal plain. The wintering range can be better understood if the distribution of the recoveries from the southeastern states in figs. 12–21 is compared with the physiographic features of these states shown in fig. 81. Band recoveries show that geese resort to nearly every river of appreciable size that dissects the Piedmont and the coastal plain, but that the numerous reservoirs are particularly favored. The coastal

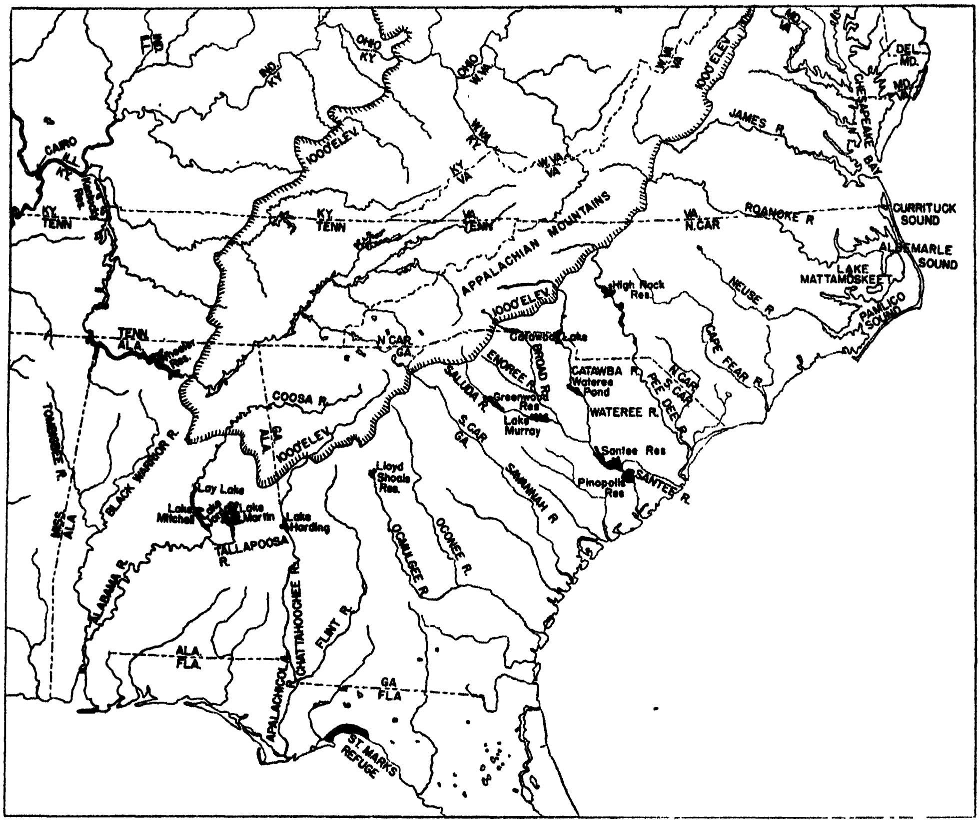

Fig. 81.—Map of the wintering grounds of the Southeast Canada goose population.

wintering range of the South Atlantic geese and the inland wintering range of the Southeast population are clearly indicated in figs. 6, 12, and 14–21.

Virginia.—Band recoveries from Canada geese banded at the Miner Sanctuary in the autumn indicate that the Southeast flyway geese wintering in Virginia concentrate in certain counties bordering the James River: chiefly Fluvanna, Goochland, Henrico, and Charles City. To a lesser extent these geese use the Mattaponi, Pamunkey, Roanoke, and Rappahannock rivers.

In a letter to Jack Miner, January 8, 1945, A. W. Smith of Richmond, Virginia, stated that about 2,000 geese frequented the James River, and another flock of about 1,500 were to be found on the Pamunkey River. As many as 15,000 geese have spent the winter in the region of Hopewell, Prince George County, according to A. P. Cutchin, a deputy warden of the United States Fish and Wildlife Service in 1939 (letter to Jack Miner from A. P. Cutchin, Atlanta, Georgia, December 9, 1939).

North Carolina.—In this state, the counties adjoining the reservoirs on the Yadkin (chiefly High Rock, but also Narrows Lake and the Norwood dam impoundment), the Catawba (Oxford reservoir), and the Rocky rivers are the principal wintering grounds of the Southeast population in North Carolina, as band recoveries indicate. According to Pearson *et al.* (1942), the reservoirs of the Yadkin River form the most important of these water areas. They report that William Birsch of the United States Fish and Wildlife Service has estimated that in one year 10,000 geese wintered in that section of the state (year of report not stated).

The Canada goose population using High Rock Lake in recent years has numbered about 600, according to W. P. Baldwin, Jr., of the United States Fish and Wildlife Service. He reports that the flock wintering

along the Great Pee Dee River and at Ansonville has recently totaled about 3,000 (personal communication, March, 1949).

South Carolina.—Pickens (1928) reported the Canada goose to be a common winter resident in upper South Carolina, a statement that is amply supported by the Miner returns of autumn-banded geese. According to Ernest F. Holland, manager of the Carolina Sandhills National Wildlife Refuge (letter to the Jack Miner Bird Sanctuary, December 18, 1946), about 5,000 Canada geese used this refuge and the adjacent Great Pee Dee River basin in the late autumn of 1945. An additional 2,500 were reported using the private waterfowl refuge of Lockhart Gaddy, located near Ansonville, North Carolina. Judged from band recoveries, Lake Murray, an impoundment of the Congaree River, is probably one of the more important bodies of water for Canada geese in South Carolina. Wateree Pond, a much smaller reservoir on the Wateree River, appears to be second in importance. Other rivers used by geese are the Broad, the Saluda (Lake Greenwood), and the Savannah (from Anderson to Aiken counties).

In several years prior to the winter of 1948–49, about 200 Canada geese wintered in the vicinity of McBee in Chesterfield County and about 250 on Lake Murray (W. P. Baldwin, Jr., personal communication, March, 1949). Another 300 frequented the section of the Savannah River bordering McCormick County. The Santee Cooper Reservoir area harbored about 250 Canada geese, the Cape Romain sector of the Atlantic Coast about 500, and Winyah Bay a small but unknown number. The Winyah Bay flock may be only a segment of the Cape Romain flock that segregates out from time to time. Data on populations at the Santee Cooper and Cape Romain National Wildlife refuges in other recent years are given in table 47.

Alabama.—According to Howell (1924), Canada geese in Alabama are "probably most abundant on the Tennessee River in the vicinity of Muscle Shoals." They are "numerous every winter in the vicinity of Montgomery. On the coast they apparently are not common, though found occasionally." Since 1942, 300 to 900 Canada geese have been reported wintering in the vicinity of the Wheeler Reservoir, according to data in the files of the United States Fish and Wildlife Service.

Sixty per cent of the Miner-banded geese reported killed in Alabama were shot in Tallapoosa, Coosa, and Elmore counties. Over half of the recoveries from these three counties are from the vicinity of Martin Lake, an impoundment of the Tallapoosa River; the remaining returns from these counties are from areas adjoining the Coosa

Table 47.—Numbers of Canada geese wintering at three national wildlife refuges in the Southeast flyway, 1934–1945.

YEAR	REFUGE					
	St. Marks		Cape Romain		Santee Cooper	
	Season	Number	Season	Number	Season	Number
1934–35	Winter	5,000	Winter			
1935–36	Winter	6,000				
1936–37	Winter	9,500				
1937–38	Winter	13,500				
1938–39	Winter	13,500	Winter	300		
1939–40	Winter	6,500	Winter	27		
1940–41	Winter	11,500	Winter	50		
1941–42	Winter	12,000				
1942–43	Winter	11,000	Winter	60	Fall	10
					Spring	20
1943–44	Winter	13,000	Winter	83	Fall	120
					Spring	50
1944–45	Winter	15,000	Winter	196	Fall	80
					Spring	50

River impoundments (Lay, Mitchell, and Jordan lakes). The flock wintering on Martin Lake numbered about 400 in the winter of 1939–40 (letter to Jack Miner from C. Robinson of Alexander City, Alabama).

Georgia.—Band recoveries from Georgia are spotty, suggesting that no great concentrations of geese occur anywhere in the state, possibly in part because of the comparative lack of large reservoirs or natural lakes. The Savannah River from Hart County to Richmond County appears to be a favored wintering area; the Ocmulgee (Lloyd Shoals Reservoir between Jasper and Butts counties), the Oconee (Washington and Laurens counties), and the Flint River (Pike, Upson, Taylor, and Crawford counties) are other sectors used by Canada geese.

Many of the recoveries from Georgia, however, may be from migrating geese rather than from wintering flocks. As a number of the recoveries are from areas of the state directly north of the St. Marks National Wildlife Refuge on the Florida Gulf Coast, it seems likely that birds en route to St. Marks contribute appreciably to the kills made in Georgia.

In 1941, 150 to 200 Canada geese were reported using Lake Harding, an impoundment created by Bartletts Ferry dam on the Chattahoochee River near West Point (letter to Jack Miner from William B. Fuller, West Point, Georgia, January 10, 1941).

Florida.—The St. Marks National Wildlife Refuge, consisting of 54,681 acres, is believed to contain the greatest single concentration of geese in the Southeast population. Although between 11,000 and 15,000 geese have wintered at this refuge since 1941, table 46, there have been singularly few band recoveries from Miner-banded geese in the surrounding country. This fact suggests that either the bulk of these geese by-pass the Miner Sanctuary on their southward migration, and hence are not banded, or that the kill in the St. Marks area is relatively small. From about 10,000 geese wintering along a 100-mile stretch of coast during the late twenties, the annual kill was said to be several hundred (letter to Jack Miner from R. G. Porter, Apalachicola, Florida, winter of 1927–28).

Future Status

Although the Canada geese of the Southeast population winter over an enormous area, extending from Virginia to Alabama and the Gulf Coast of Florida, their total number is not large. With the exception of the flock in the St. Marks area, most of the concentrations can be classified as being either small to medium in size and, in the aggregate, may match the St. Marks flock in size. Therein may lie the security of the Southeast population. The small concentrations, by virtue of their size, do not attract other than local hunters, whose kill is probably fairly light. The paucity of band recoveries from the St. Marks area suggests the possibility that the flock there is afforded adequate protection by the St. Marks National Wildlife Refuge.

In any management measures involving the Southeast population, recognition should be given to the fact that the scattered flocks are but segments of a more or less contiguous population on the breeding grounds. These segments should be carefully censused at the time of the annual January inventory and the extent of the kill in each wintering area should also be determined within fairly close limits. To help insure the perpetuation of this population, it may be necessary to declare at least a portion of all reservoirs important to wintering geese, and some adjacent land areas, inviolate to hunting.

Insofar as their habitat requirements in winter are concerned, Canada geese can be considered adaptive birds. They are quick to respond to changing agricultural practices, to the creation of reservoirs, and to the formation of new refuges by changes in their habits and their local distribution. W. P. Baldwin, Jr., reported (personal communication, March, 1949) that increasing numbers of Canada geese are wintering in northern Georgia, where they are resorting to the cultivated fields. At least some of these geese in former years must have migrated down to the St. Marks area. Such "reshuffles" in the population and the problems that arise from them should be recognized in any attempts to manage the Southeast geese.

APPENDIX B

CLASSIFICATION OF THE CANADA GEESE OF THE GENUS *BRANTA*

PROBABLY few other groups of North American birds have presented the taxonomists with greater challenge than the white-cheeked geese of the genus, *Branta*. Before the distribution and the relationships of the various races can be fully understood, much collecting and banding will have to be done on the breeding grounds. The complexity of the problem is apparent when it is realized that the race *Branta canadensis interior* alone can be broken down into four fairly distinct breeding populations. As might be expected, the literature on the genus is fairly voluminous and often contradictory. Some plumage variations once thought to have taxonomic significance have been shown to be merely variations within single populations (Taverner 1931, Elder 1946, Hanson 1949*b*). In the latest revision of the genus by Hellmayr & Conover (1948), the characters of the downy plumage were taken into consideration. This factor considerably enhances the reliability of their study over studies previously made. They list the various members of the genus as follows:

> *Branta leucopareia leucopareia* (Brandt). Tundra goose. [The lesser Canada goose of Kortright (1942) and others.]
>
> *Branta leucopareia occidentalis* (Baird). West Coast goose. [The Western Canada goose of Kortright (1942) and others.]
>
> *Branta minima* Ridgway. Cackling goose.
>
> *Branta canadensis parvipes* (Cassin). Lesser Canada goose. [See Aldrich (1946) regarding the resurrection of *parvipes*.]
>
> *Branta canadensis moffitti* Aldrich. Great Basin Canada goose.
>
> *Branta canadensis interior* Todd. Todd's Canada goose.
>
> *Branta canadensis canadensis* (Linnaeus). Eastern Canada goose.
>
> *Branta hutchinsii* (Richardson). Richardson's goose. [*Branta canadensis hutchinsi* of Kortright (1942) and others and sometimes known as Hutchins's goose.]

Taverner (1931) has pointed out that several of the races are markedly distinct in the field, but as skins in the laboratory they are separated only with difficulty. According to James Mark, an Indian living at Eastmain, four different kinds of Canada geese are recognized by the James Bay Indians. The bird called *Muskego nisku* by the Cree Indian, meaning "large swamp goose," is the breeding goose of the muskeg, *Branta canadensis interior*, fig. 82. The "coast goose," *Winnipego nisku*, is restricted to the James Bay coasts and observed only while on migration. It is reported as being smaller than the swamp goose, more vociferous, and having a relatively shorter neck, a description that fits the lesser Canada goose, *Branta leucopareia leucopareia*. Richardson's goose, *Branta hutchinsii* is called *Apichishkish*, meaning literally a small goose that has attained its full growth, fig. 82. The fourth kind recognized by the Indians on the south and east coasts of James Bay is described as being the largest of the group and possessing a brown breast, a feature from which it has derived its name, *Kaoosoupasawat nisku*. Geese of this kind are reported to breed farther north and are called the Fort George (Quebec) geese by the Moose Indians. The brown breast may represent staining by iron-rich waters of the areas frequented by this bird, which may possibly be *B. c. interior*.

It is of interest to note that Blakiston (1863) also reported that an Indian on the Saskatchewan River described four different kinds of "grey geese," the common gray goose, a short-necked goose, a small goose, and a large goose, descriptive names that roughly fit the forms described by the Indians of James Bay.

The chief of the Indians around Lake St. Martin, Manitoba, told Taverner

Fig. 82.—Profile views of (upper head) an interior Canada goose, *Branta canadensis interior* and (lower head) a Richardson's goose, *Branta hutchinsii.* Both specimens are juvenile males.

(Shortt & Waller 1937) that three kinds of Canada geese visit their area. The descriptions of these three varieties fit *canadensis, leucopareia,* and *hutchinsii.* According to Taverner's unpublished notes, which Shortt & Waller quote, an immense kind of Canada goose is also traditional with these Indians and "is so rare that it is known only by report. It is probably mythical."

Despite Taverner's disbelief at one time in the reality of a very large goose, Mershon (1925) leaves little doubt that a very large variety of honker existed. McAtee (1944) has also commented on records of large geese from the Plains region. Aldrich (1946) has now recognized this large race of Canada geese, giving it the name *moffitti.* Individuals of this race, presumably adult males, are known to range as high as 14 to 16 pounds, and even greater weights than these have been reported. Elder (1946) weighed 2,179 geese and the senior author weighed several thousand more geese at Horseshoe Lake, Illinois, without encountering an individual that attained the weight of 12 pounds.

In the light of our present knowledge, the very large, almost legendary Canada goose known to many Indian groups in the boreal forest of Canada might be explained by individuals of the race *Branta canadensis moffitti* that have been occasionally taken north of their normal range. Such occasional invasions of the breeding grounds of one subspecies of Canada geese by nonbreeding members of another adjacent subspecies would not be unexpected. (In the above case the invasion of the range of *B. c. interior* by individuals of *B. c. moffitti* or an even larger extinct variety.) In the summer of 1949, Peter Scott, British ornithologist, and the senior author observed several flocks of nonbreeding "honkers," *B. c. moffitti* or *interior,* in the Perry River (Northwest Territories) breeding grounds of the smaller tundra Canada goose, skins of which have been identified by the senior author as those of *Branta leucopareia leucopareia.*

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Biology of the White Crappie *in Illinois*

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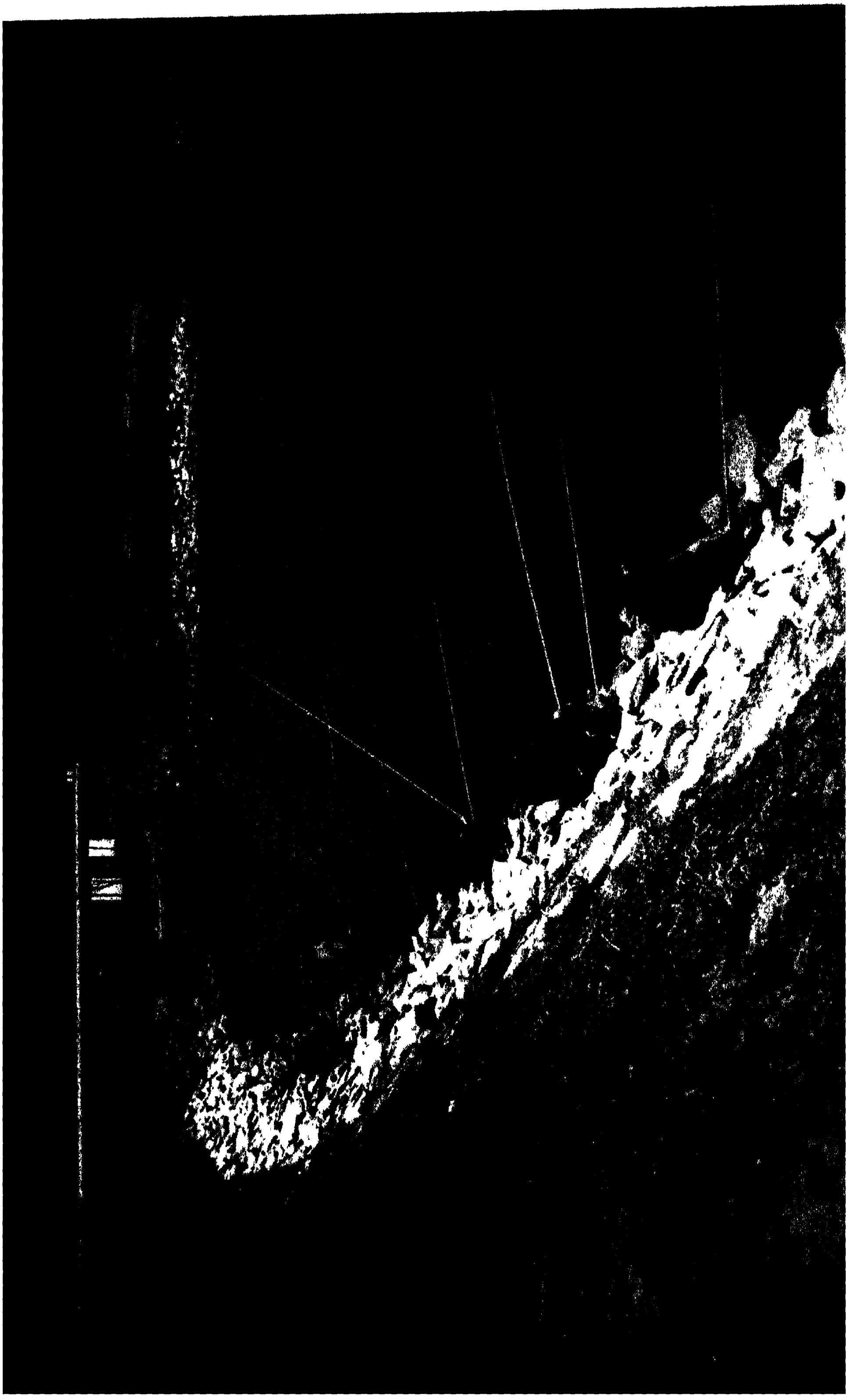
CONTENTS

The frontispiece shows fishermen congregated along a riprapped approach to one of the highway bridges across Lake Decatur. (Photograph from Decatur *Herald-Review.*)



Biology of the White Crappie *in Illinois*

DONALD F. HANSEN

THE white crappie, *Pomoxis annularis* Rafinesque, and the black crappie, *Pomoxis nigro-maculatus* (Le Sueur), are among the most characteristic and abundant fishes of the lakes and streams of Illinois. They are popular with Illinois anglers and are generally ranked with the better food fishes of the state. Both species have been used extensively for stocking artificial lakes of various sizes.

This paper is based largely on white crappie studies carried on by the writer at Lake Decatur, Macon County, Illinois, during the period beginning in late November, 1935, and ending in early December, 1939. Most of the fish for the Lake Decatur studies were caught in hoop nets that were operated at 1- to 2-month intervals at all seasons of the year.

Year-round collecting at Lake Decatur provided material on the white crappie for determination of spawning time, length of the annual growing period, seasonal fluctuations in plumpness, time of year of high natural mortality, and date of annulus formation. In addition, this collecting brought to light seasonal variations in sex ratios and evidence that the hoop net is less efficient for capture of crappies in warm weather than in cold weather.

Pronounced yearly differences were observed in time of annulus formation (Hansen 1937), length of growing period, size and age distribution, and rate of growth of the white crappie.

Included with information from Lake Decatur is some additional information about crappies that was obtained from other places in the state as a result of field investigations by various members of the Natural History Survey staff during an 18-year period beginning in 1927.

ACKNOWLEDGMENTS

Most of the crappie information from waters of the state other than Lake Decatur was collected during fisheries investigations carried on by Dr. David H. Thompson while head of the Section of Aquatic Biology of the Natural History Survey. His unpublished observations on length, weight, sex, lymphocystis disease, day and night rates of hoop-net capture, and angling represent important contributions to the paper.

Nearly everyone who worked in the Section of Aquatic Biology of the Natural History Survey in the 18-year period beginning in June, 1927, had a part in the collecting of field data. Francis D. Hunt undoubtedly measured more fish and gathered more scale samples from all parts of the state than any other person. Dr. Louis A. Krumholz helped with all the Lake Decatur collecting from late 1938 through 1939.

During the period of intensive field work at Lake Decatur, Sam A. Parr, then employed by the city of Decatur as lake inspector, and Ely Mooreland, caretaker at Faries Park, furnished information about the lake, helped to provide places to work during bad weather, and sometimes assisted with netting operations.

Photographs of Lake Decatur were lent by the Decatur *Herald-Review*.

The entire manuscript was read by Dr. George W. Bennett, Dr. Elizabeth B. Chase, and James S. Ayars, and parts were-read by Agnes C. Hansen and Dr. William C. Starrett. Each offered valuable criticism.

I am especially indebted to Dr. Bennett and Dr. Thompson for what they have contributed through discussion.

METHODS AND TECHNIQUES

Because the white crappies used in this study were taken from a number of different waters, by different collectors, and over a considerable period of time, several methods of collection and techniques of study are represented.

Collections

With the exception of two collections from hook-and-line catches, all of the fish taken from Lake Decatur for this study were trapped in 1-inch-mesh hoop nets, that is, fykes or wing nets, each having a pot or rear compartment of 1-inch mesh (square measure). Most of the fish from other waters also were taken with 1-inch mesh hoop nets, but some fish were taken with hoop nets and seines of other mesh sizes, with hook and line, with rotenone poison, and by draining lakes. The methods of capture are specified throughout the paper in connection with discussion of the data. The 1-inch-mesh hoop nets retain white crappies as small as 4 inches total length. The fish of this length are usually a little over a year old. No effort was made at Lake Decatur to sample fish of lengths less than 4 inches.

Hoop nets of the type used at Decatur and at most other collecting stations are made of netting stretched over a series of wooden hoops to form a cylinder 10 or 12 feet long and usually 3½ to 4½ feet in diameter. Each net is divided into two compartments. A funnel-shaped entrance leads fish into a front compartment; a second funnel leads them into a rear compartment or pot. A "fingerthroat" is used at the inner funnel opening to help prevent reverse movement, that is, prevent escape of fish from the pot. Wings 10 feet long are attached on either side of the hoop at the open end and serve to guide fish into the trap. Ordinarily a separate lead net, 40 to 60 feet long, is used with each hoop net. Two poles, one at the outer end of each of the wings, and a third, at the end of the pot, are pushed into the lake or stream bottom to hold the net in the "set" position. The lead net is secured in a similar manner. The mesh of the lead, wings, and front compartment of the hoop net is 1½ inches square, while the mesh of the rear compartment, or pot, is 1 inch square. Designations of mesh size of hoop nets mentioned in this paper refer to the mesh of the pot.

At Lake Decatur and elsewhere, the hoop nets were set usually with a few inches of net standing out of water. For example, a 3½-foot-diameter net was set where the water was about 3 feet deep. The period between setting the nets and emptying them varied ordinarily from 1 to 3 days.

Two winter hoop-net collections were made at Lake Decatur after the formation of heavy ice over most of the lake. In January, 1938, nets were set in a place that was kept open by warm water from the A. E. Staley plant. This water, which flowed into the lake from a ditch just above Nelson Park, fig. 1, originally was pumped from the lake into a cooling system within the plant, where in the cooling operation it was warmed; it was then returned to the lake. In January, 1939, the nets were set in an open area between the old and new Illinois Terminal Railroad bridges, three-fourths of a mile below Faries Park, fig. 1, on the upper west side of Lake Decatur. Neither at Lake Decatur nor elsewhere were nets operated under the ice.

Length Measurements

Most white crappies included in this study were measured in inches, to the nearest tenth of an inch, on calibrated measuring boards. The 1933 collection of crappies from Senachwine Lake was measured in millimeters.

Standard length was the basis of measurement before January, 1939, and total length after that date. Total length was measured from the tip of the lower jaw to the end of the longest ray of the tail with the mouth of the fish closed and

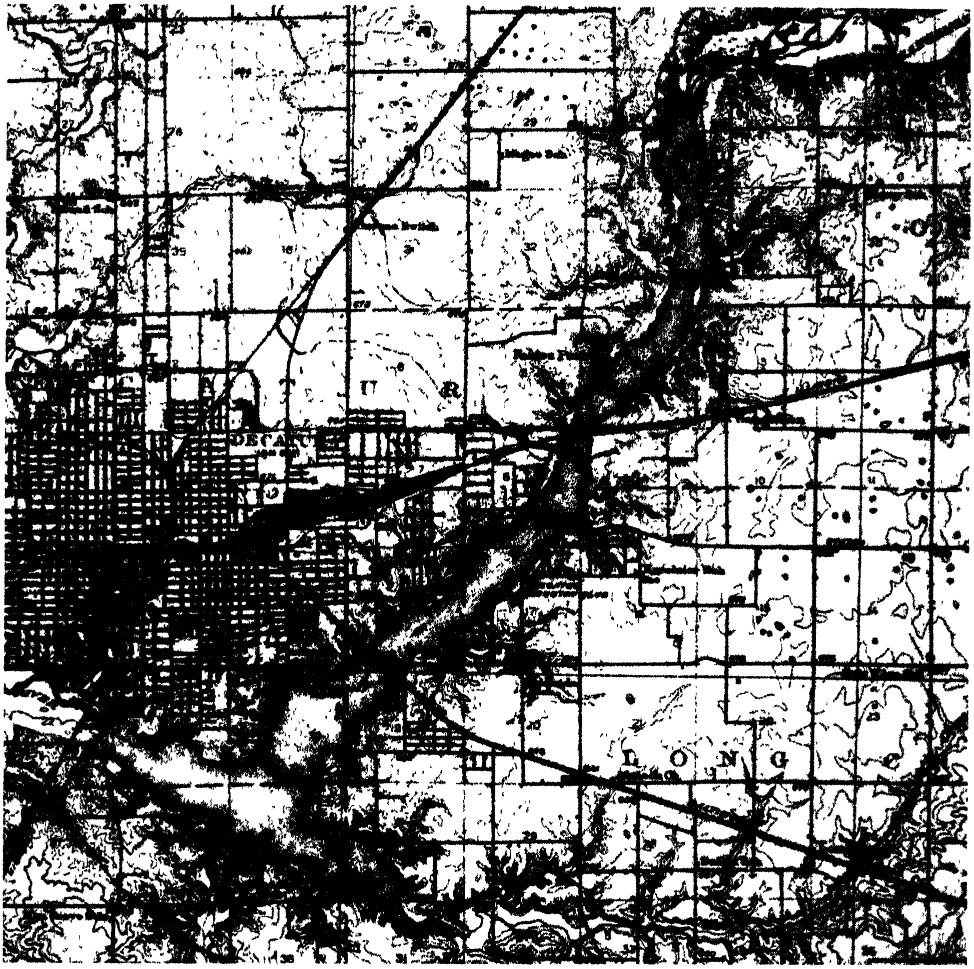


Fig. 1.—Lake Decatur and connecting streams, from the U.S. Coast and Geodetic Survey Decatur Quadrangle.

with the rays of the tail laid parallel rather than fanned. Standard length was measured from the tip of the lower jaw to the crease at the base of the tail. This crease marks the anterior end of caudal rays and is a little forward of the last scales on the tail. The standard-length measurements were converted into total lengths for this paper, except that standard lengths were used in computing coefficients of condition and in discussing length-weight relationships.

Length classes are designated in this paper by class center. Three different class intervals were used: one-half inch, 1 inch, and 1½ inches. Fish were assigned to length classes as illustrated by the following examples from the class intervals:

One-half-inch class interval: 5-inch class (4.8–5.2 inches); 5½-inch class (5.3–5.7 inches).

1-inch class interval: 5-inch class (4.6–5.5 inches); 6-inch class (5.6–6.5 inches).

1½-inch class interval: 6-inch class (5.3–6.7 inches); 7½-inch class (6.8–8.2 inches).

Weight Measurements

Lake Decatur crappies were weighed on a Chatillon dietetic spring balance of 1,000 grams capacity. The dial of the scale was marked at 4-gram intervals, and readings were made to the nearest 4-gram mark.

The fish were iced if necessary to prevent their spoiling when more than a day was required to handle large collections. The 1933 Senachwine Lake crappies 2 inches or more in length were weighed to the nearest one-tenth gram; those less than 2 inches long were weighed to the nearest one-hundredth gram. The crappies from Horseshoe Lake and Craborchard Lake were weighed to the nearest one-hundredth pound. The Senachwine Lake crappies were carefully wiped to remove excess water before being weighed. This practice was not followed elsewhere.

During the first several hours after death it is possible that fish, if kept in water, gain slightly in weight. Repeated weighings of a white crappie that before death had a total length of 8.5 inches and a weight of 148 grams showed after death a weight increase of 2 grams in 4 hours and 6 grams in 7 hours. This fish was kept in ice water between weighings.

There may also be a slight decrease in body length after death which, together with the increase in dead weight over live weight, would tend to give a dead fish a higher coefficient of condition than a live one. Whether this weight change is typical or not, it probably had only a minor effect on the conclusions reached from the length-weight study of the Lake Decatur fish, since measuring and weighing usually were completed within 4 to 5 hours after the fish were removed from the nets.

Identification of Sexes

Differences in breeding coloration were not usually relied upon as a method of distinguishing sex. This method was used for a single collection (June 2–5, 1947) at Lake Decatur, and was also used by Dr. David H. Thompson for his observations on sex in the Illinois River valley in 1942. As shown by tests, however, this method is not entirely reliable, and the rule at Lake Decatur was to dissect a fish when neither eggs nor sperm could be squeezed from the genital opening.

Scale Collections

Thirty to 50 scales were removed from the left side of each fish in the region between the dorsal spines and the lateral line. At Lake Decatur, to avoid the accidental mixing of scale samples, scaling tools were rinsed after scales had been taken from each fish.

Scale Analyses

Fish ages were determined by counting the number of annual rings on the scales. About half the scale examinations were made with a low-power, binocular, dissecting microscope on uncleaned, unmounted, dry scales. The other examinations were made from the projected images of cleaned scales mounted on slides in glycerine jelly or Farrant's medium.

Interpretation of the growth rings is discussed in the section that deals with age and growth. Age readings were made on practically all white crappie scale material collected in Illinois for the Natural History Survey up to January, 1939, and on some material collected later.

With the following exceptions, age determinations are those of the author: Lynn Hutchens read the scales collected at North Lake, November, 1931, Lake Chautauqua, November, 1936, and Weldon Springs Lake, July, 1936; William Hoyer (National Youth Administration) read the scales collected at Senachwine Lake, August–November, 1933. Hutchens read the Lake Decatur scales collected in March–August, 1937; most of the June–August collections of that year were reexamined by the author.

Sampling Procedure

At Lake Decatur, and usually elsewhere, data from hoop nets were obtained from entire catches; no attempt was made to select fish of any particular size. However, about one-third of the scale material from the rest of the state was collected during a Natural History Survey tagging experiment in which only specimens longer than 6 inches were used. Also, some of the fish which the Survey tagged were caught by commercial fishermen, and field notes did not always show whether these fishermen had furnished their entire catches or not. It can be assumed that anglers, from whom some of the data were obtained, did not in all cases keep all of their small fish.

Periods of Study

The over-all period covered by the Lake Decatur collections was late November, 1935, to early December, 1939. Length measurements and scale samples were obtained from all Lake Decatur collections. Weighing was begun in early April, 1936, and continued through 1939. Sex, whether male or female, was recorded at two periods, late May, 1936, through July, 1937, and November, 1938, through December, 1939; records were kept of ripe fish taken at spawning time in 1936, 1937, and 1939.

Age readings and the study of length-weight relationships were terminated with the collection of January 9, 1939. The later 1939 collections were used in the study of size distribution, sex ratio, and seasonal variations in rate of hoop-net capture.

Study Limitations

In certain phases of the Lake Decatur study, analyses were made on the basis of broods. Fish hatched in the same calendar year constituted a brood. Because the brood assignments in collections made in May and June, 1936, at the time of annulus formation were thought to be particularly open to question, the collections taken during those months were not used in making certain analyses.

In general, the study of broods was limited to those from which fish were taken in greatest abundance over the longest periods. The older broods, which disappeared from net catches shortly after the beginning of observations (broods hatched in 1930–1932), were omitted from most analyses.

Some entire collections, or parts of collections, were omitted from consideration when a breakdown of data into several categories resulted in poor representation.

Two collection dates that appear in some of the tables, one in May, 1937, and one in May, 1939, were based on observations of fish caught by anglers. These dates are, therefore, not represented in the tables showing rate of catch in hoop nets.

CRAPPIE DISTRIBUTION

Both the white crappie and the black crappie were reported by Forbes & Richardson (1920) as occurring in lakes and streams throughout Illinois. The black crappie was reported as the more common species in the glacial lakes of northeastern Illinois, and the white crappie as the more common in the creeks of the state.

Relative abundance of the two species tends to vary sharply in hoop-net sampling, which has provided most of the recent data on distribution of crappies in this state. Although no assurance can be given that net sampling has been adequate in all the localities sampled, it is believed that the relative abundance of the two species has been correctly represented for the various categories of lakes and streams discussed.

In all Illinois water-supply reservoirs that have been intensively studied, white crappies were found to be more abundant than blacks. The whites made up at least 95 per cent, and the blacks 5 per cent or less, of the large number of crappies caught with hoop nets in three reservoirs, Decatur, Craborchard, and Pana; the whites were the only crappies caught in Lake Springfield. The hoop-net observations at Lake Springfield and Lake Decatur were verified by observations of the hook-and-line catch in these reservoirs.

The predominance of white crappies in these reservoirs may be due to one or several factors, three of which are suggested here: (1) a possibly greater suitability of the reservoir habitat for white crappies, (2) a probable predominance of white crappies in feeder streams, (3) a possibly heavier artificial stocking of white crappies.

In most ponds studied by the Natural History Survey, white crappies were found to outnumber blacks. In a poison census of 22 ponds of 12 acres each or smaller (Bennett 1943), both species were found in 14 ponds, only whites were found in 3, and only blacks in 3. In the 14 ponds in which both species were found, whites predominated by weight in 10, blacks in 1; only traces of the two species were found in 3 ponds.

One possible explanation of the predominance of whites in most of the ponds may be the more common occurrence of these fish in "creeks" (Forbes & Richardson 1920), the source of many of the fish used in stocking ponds. The green

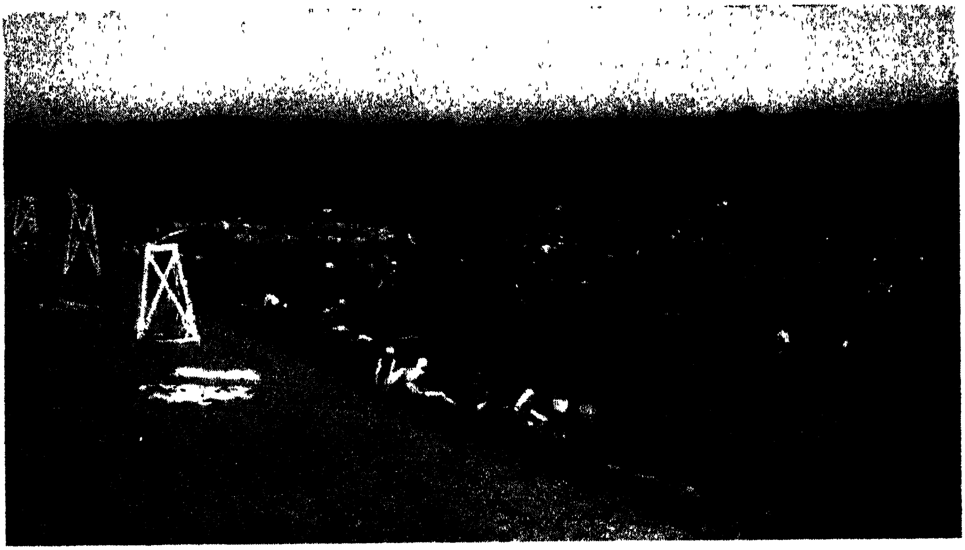


Fig. 2.—Public bathing beach at Nelson Park, Lake Decatur, in July, 1943. (Photograph from Decatur *Herald-Review.*)

sunfish, a typical creek species, was found in all but 1 of the 22 ponds censused by Bennett. Another possible explanation may be a predominance of whites in the natural stocking that takes place from feeder streams or from nearby streams that overflow in times of high water. Still another explanation may be a greater suitability of the pond habitat for the whites.

In bottomland lakes bordering the Illinois River, the predominance of one species over the other is not striking. Both species seem to be abundant. Of the crappies taken in a 1942 hoop-net survey of the Illinois River and its bottomland lakes, 56 per cent of the total crappie catch from the lakes were blacks. In collections from most of these lakes, the blacks predominated. In collections from the only two bottomland lakes sampled along the Ohio River, the whites predominated.

In the main channel of the Illinois River, the predominance of the blacks is more pronounced than in the bordering lakes. Of the crappies taken from the main channel in the 1942 survey mentioned above, 73 per cent were blacks. Of the crappies taken in 1944 and 1946 hoop-net surveys of Mississippi River navigation pools (pools 12–26) extending from Dubuque, Iowa, downstream to Winfield, Missouri, approximately two-thirds were whites.

Data on the following rivers in which both species of crappies occur may not give a true picture of relative abundance, since, in spite of intensive netting operations, rather small numbers of crappies were caught. Records show that more blacks than whites were taken in the Des Plaines River, but that more whites than blacks were caught in the Rock, Kaskaskia (Luce 1933), and Ohio Rivers.

Hubbs & Lagler (1947) stated that the black crappie is less common than the white crappie in silty waters. The relation between siltiness and the predominance of one species over the other is not clearly apparent in the Illinois waters studied. The black crappie, for instance, predominates in some of the silty waters of the Illinois River valley as well as in comparatively non-silty glacial lakes of the northeastern corner of the state.

DESCRIPTION OF LAKE DECATUR

Lake Decatur, fig. 1, is a city water supply reservoir made in 1922 by damming the Sangamon River at Decatur, 75 miles below its source. While the lake was built primarily to meet the home and

industrial water needs of a manufacturing center, recreational uses that include fishing, swimming, and boating are encouraged by the city, figs. 2 and 3.

The lake is 10.4 miles long and varies from one-fourth to three-fourths of a mile in width; its original area was 2,805 acres. In 1936 Glymph & Jones (1937) found a depth of 15 feet at the dam and a depth of 6 feet midway in the lake between upper and lower ends.

Oxygen analyses made on July 29,

Fig. 3.—Sail boating on Lake Decatur; the *Aloha* in 1939. (Photograph from Decatur *Herald-Review*.)

1932, by D. J. O'Donnell, then of the Natural History Survey, indicated a fairly uniform distribution of dissolved oxygen from surface to bottom.

Ice covers most of the lake for about 2 or 2½ months of the year. Some dates of ice departure were February 23, 1936, February 28, 1939, and March 13, 1940.

Glymph & Jones (1937) showed that during the first 14 years of impoundment, 1922–1936, sediment had been laid down on the bottom to a depth that averaged 1 foot near the dam and increased gradually to 2 feet in the upper portion of the lake. Deposits of sediment from 3 to 7 feet thick were measured in the old river channel in the main part of the lake. The river channel above the lake had remained quite clear of deposits as a result of the scouring action of floods. The accumulation of sediment in Lake Decatur had resulted in a loss of 14 per cent of the original storage capacity of the reservoir, or 1 per cent per year. According to Brown, Stall, & De Turk (1947), the rate of loss increased to 1.2 per cent per year during the period 1936–1946. In *The Story of a Lake,* Walker (1949) has given a popular account of the silting of Lake Decatur.

The turbid condition of Lake Decatur probably accounted for the scarcity of aquatic plants at the time of this study. While in some places there were extensive beds of water primrose (*Jussiaea* sp.), arrowhead (*Sagittaria* sp.), and cattail (*Typha* sp.), most of the shore line was bare of emergent aquatic plants. No plants of strictly underwater habit were recorded, although they may have been present in some areas.

The bottom fauna of this lake was studied by Gersbacher (1937) and the plankton by Eddy (1932).

A list of the species of fish and numbers of each kind caught in Lake Decatur with hoop nets from April, 1936, through September, 1937, is shown in table 1. The species composition of anglers' catches at Lake Decatur as observed in partial censuses is shown in two tables: table 2, representing counts by the writer of the catches of 71 fishermen who were using

Table 1.—Species and numbers of fish caught in 1-inch mesh hoop nets at Lake Decatur during the period April, 1936, through September, 1937.

Species*	Number of Fish Caught
Shortnose gar, *Lepisosteus platostomus* Rafinesque	6
Gizzard shad, *Dorosoma cepedianum* (Le Sueur)	614
Buffalofishes, *Megastomatobus cyprinella* (Valenciennes), *Ictiobus niger* (Rafinesque), and *I. bubalus* (Rafinesque)	268
Carpsucker, *Carpiodes* sp.	292
Spotted sucker, *Minytrema melanops* (Rafinesque)	1
White sucker, *Catostomus commersonnii* (Lacépède)	3
Redhorse, *Moxostoma* sp.	119
Carp, *Cyprinus carpio* Linnaeus	141
Golden shiner, *Notemigonus crysoleucas* (Mitchill)	3
Channel catfish, *Ictalurus lacustris* (Walbaum)	150
Yellow bullhead, *Ameiurus natalis* (Le Sueur)	1
Black bullhead, *Ameiurus melas* (Rafinesque)	160
Flathead catfish, *Pilodictis olivaris* (Rafinesque)	4
Pike, *Esox lucius* Linnaeus	2
White crappie, *Pomoxis annularis* Rafinesque	2,531
Black crappie, *Pomoxis nigro-maculatus* (Le Sueur)	123
Warmouth, *Chaenobryttus coronarius* (Bartram)	1
Green sunfish, *Lepomis cyanellus* Rafinesque	3
Bluegill, *Lepomis macrochirus* Rafinesque	97
Pumpkinseed, *Lepomis gibbosus* (Linnaeus)	8
Largemouth black bass, *Micropterus salmoides* (Lacépède)	29
Yellow perch, *Perca flavescens* (Mitchill)	22
Yellow bass, *Morone interrupta* Gill	880
Freshwater drum, *Aplodinotus grunniens* Rafinesque	391

* Common and scientific names from American Fisheries Society Special Publication No. 1 (Anonymous 1948).

Table 2.—Species and numbers of fish caught with live minnows by 71 bank fishermen at Lake Decatur, as shown by stringer counts in May, 1937, and May, 1939.

SPECIES	NUMBER OF FISH CAUGHT MAY 16, 1937, BY 13 FISHERMEN	NUMBER OF FISH CAUGHT MAY 17–20, 1939, BY 58 FISHERMEN
Channel catfish	—	5
Flathead catfish	1	1
White crappie	86	102
Black crappie	1	—
Green sunfish	2	—
Sunfish*	—	1
Largemouth bass	1	—
Yellow bass	1	—
Freshwater drum	4	3
Total	*96*	*112*

* Kind not specified

Table 3.—Kinds and numbers of fish caught with earthworms by Harold Taylor in year-round fishing at Lake Decatur; 179 trips during the years 1934–1938.

KIND OF FISH*	NUMBER OF FISH CAUGHT
Buffalo	3
Silver carp	1
Sucker and redhorse	9
Carp	169
Channel cat	113
Bullhead	1,089
Flathead cat	2
Crappie	11
Sunfish	160
Yellow bass	245
Sheepshead	690
Total	*2,492*
Total weight, 1,012 pounds	

* Names of fish are those used by Harold Taylor in his records. The sheepshead is the same fish as the freshwater drum

live minnows for bait, and table 3, showing the catch of one fisherman, Harold Taylor, in the course of 179 trips (mostly at the head of the lake), in year-round fishing over a 5-year period. While Taylor's personal record shows that a variety of species could be caught in the lake, there was relatively little fishing for any kind but crappies. Many Decatur residents and many people from surrounding towns took advantage of the crappie fishing. Stringers examined at Lake Decatur in 1937 and 1939, table 2, as well as those examined in 1935, contained many more white crappies than black crappies.

SPORT FISHING

At Lake Decatur, fishermen interviewed during the period of field work reported that they caught white crappies principally from March 1 to June 1 and that midsummer fishing was a waste of time for most of them. In 1935, however, crappies continued to bite well until mid-July. In some Illinois localities crappie fishing is less confined to the spring months than at Lake Decatur and in a few is continued during most of the year.

At Lake Chautauqua, the most productive crappie fishing in 1941 and 1942 came in May and June (Hansen 1942), while the best fishing in 1944 came between mid-July and mid-September. A 12-year fishing record for Rinaker Lake, Macoupin County, studied by Dr. David H. Thompson (unpublished) showed that June, July, and October were the best months for crappie fishing at that lake, with July somewhat better than the other 2 months. Illinois crappies sometimes bite well in midwinter as shown by excellent catches made in January of some years in open water areas at the edge of Lake Chautauqua. The numbers and kinds of crappies caught have not been recorded and may have included both species.

At Lake Decatur, during the period of this study, crappie fishermen generally fished on the approaches to the several railroad and highway bridges that cross the lake. Here most of them sat on the broken concrete riprap and fished with cane poles and live minnows, frontispiece. At this lake, fishermen did little crappie fishing from the natural lake shore or from boats.

In most other parts of Illinois, as at Lake Decatur, still fishing with live minnows is doubtless more common than casting, trolling, or fly fishing. At Rinaker Lake, however, the preferred method is trolling with either live or dead minnows. According to Evermann & Clark (1920), trolling was at one time a favorite method of taking crappies at Cedar Lake, Indiana.

Large crappies are occasionally caught on bass plugs. Worms and artificial fly-rod baits are effective at times. Larry Simandle, who, while living at Canton, often fished for crappies with artificial baits at Lake Chautauqua, recommended the following fly-rod baits: Paulson's Pilk (weedless) with pork rind, Pflueger Pilot flies, Pflueger Pippin Wobbler, and four patterns in trout flies—white miller, red ibis, royal coachman, brown hackle.

Robert Page Lincoln, outdoor writer, is credited with describing a trolling lure that he considered as good a crappie bait as a live minnow. This bait consisted of a strip of freshly caught fish measuring a little over an inch in length (with skin on one side) placed on a hook below a one-half to three-quarter inch gold-plated spinner; a 4-foot gut leader was used between the spinner shaft and line.

A few fishermen employed special methods and were successful in catching crappies at Lake Decatur throughout the summer. The method described by F. F. Zehnpfund involved wading near the bank where the water was 1 or 2 feet deep and slowly bobbing a minnow up and down near projecting sticks and brush. This fisherman emphasized that where obvious cover, such as brush, was scarce he did not overlook the most isolated projecting weed stalk as a possible place to catch a fish.

Robert Witke used a different method for catching crappies in the summer: A stake was driven into the lake bottom with 2 or 3 feet left projecting above the water. A line with hook attached was fastened to the top of the stake so that a live minnow placed on the hook was able to swim only in a small area close to the surface. The crappies then came to the surface to take the bait.

Mr. and Mrs. O. D. Zook of Springfield have fished for white crappies in Lake Springfield for many years and have established for themselves a local reputation as expert crappie fishermen. While most fishermen at Lake Springfield, like those at Lake Decatur, have difficulty in catching crappies in midsummer, Mr. and Mrs. Zook have usually been able to catch these fish from early spring to late fall by varying their fishing methods with season of the year. They use artificial lures as well as minnows. Mr. Zook, who specializes in artificial fly-rod baits, has had success with a small spinner and white fly combination and with various all-metal baits (Pflueger Pippin Wobbler, Arbogast Tin Liz, South Bend Trix Oreno) and with homemade baits patterned after the baits named. He is of the opinion that these metal baits are improved by replacing their metal "flippers" with a strip of thin white rubber, one-eighth inch wide by 1 inch long, tapered to a point. He has used artificial lures mainly in his spring and fall fishing.

The Zooks fish with minnows in shallow water in the spring but in deep water in the summer; in early spring from a bank where the water is only 1 or 2 feet deep, and later, in May and June, from a boat dock where the water is 6 to 8 feet deep. When the weather becomes hot and they can no longer catch crappies from the boat dock, they fish with minnows from a boat in a submerged creek channel at a depth of 10 to 15 feet. These two fishermen believe that locating concentrations of fish is one aspect of successful crappie fishing and making the crappies bite is another. Mrs. Zook has written as follows:

"Sometimes a foot in depth or a foot to one side or the other makes a difference of an empty or full stringer. I bob the minnow up and down—move it sideways through the water—change spots if it is only a few inches. I keep the minnow moving constantly. If the crappies don't hit almost as soon as the minnow is dropped in, you may as well move around and aggravate them until they do hit. I know it is possible to do that. In the spring I saw a 14-inch crappie in the boat house; it took me 25 minutes to catch him. If ever a crappie was aggravated, he was. I dangled a minnow all over him—it was interesting how he would knock the minnow out of his way."

The Zooks believe that crappies like to stay in and around brush and snags, and that these fish sometimes show a preference for small minnows over large minnows. Two Peoria Lake fishermen were sure that large-size crappies, kind not mentioned, preferred small minnows while medium-size crappies were not so particular about the size of the minnows.

In Lake Springfield, where most of the crappies are small, the Zooks usually made

their best catches of large crappies during the first 3 weeks in May and continued to make good catches of small crappies for several weeks longer.

Many fishermen keep quite small crappies when large ones are scarce. Of 32 stringers containing white crappies examined at Lake Springfield, May 22–25, 1941, 30 stringers contained white crappies that measured 7 inches or less, total length. A grouping of the 296 white crappies found on the 32 stringers into half-inch length classes showed that 66 per cent fell in the 5½- to 7-inch classes, 27 per cent in the 7½- and 8-inch classes, and 7 per cent in the 8½-inch class or above.

NET SAMPLING

In hoop-net fishing for crappies, variations have been found in the rates of capture at different seasons; also, in the

Table 4.—Seasonal variation in rate of capture of white crappies in 1-inch-mesh hoop nets in Lake Decatur.

Date of Collection	Sampling Station	Number of Nets	Net-Days	Number of White Crappies Caught	Number per Net-Day
1935					
Nov. 22	Faries Park	2-3	3	78	26
1936					
April 3	Faries Park	3	16	326	21
May 4–6	Faries Park	1	4	75	19
May 29–June 4	Faries Park and Big Creek	1	7	100	14
June 22	Faries Park	1	3	15	5
July 3–5	Big Creek	1	6	48	8
July 31–Aug. 3	Big Creek	1	5	73	15
Sept. 8–14	Big Creek	1	6	29	5
Sept. 22	Nelson Park Beach	2	4	61	15
Oct. 24–27	Faries Park	3	12	240	20
Dec. 21	Staley's Outlet	3	15	297	20
1937					
March 1–4	Faries Park	2	16	666	41
April 24	Faries Park	2	6	117	20
June 3–5	Faries Park	3	12	233	19
June 24	Faries Park	3	9	140	16
July 10–16	Faries Park	3	27	94	3
Aug. 6–14	Big Creek, Lost Bridge, and Beverly Heights	3	30	74	2
Sept. 22.	Faries Park	3	6	218	37
Nov. 3	Faries Park	3	6	170	28
1938					
Jan. 17–24	Staley's outlet	3	17	18	1
March 14	Faries Park	3	9	266	30
May 28	Faries Park	4	8	108	14
July 1–14	Faries Park	3	9	42	4
Aug. 25	Faries Park	7	14	79	6
Oct. 6	Faries Park	4	10	67	7
Nov. 4–11	Faries Park	3–4	20	75	4
1939					
Jan. 9	¾ mile below Faries Park	4	12	159	13
March 24	Faries Park	4	16	315	20
May 3	Faries Park	4	8	148	19
May 29	Faries Park	4	12	122	10
June 20	(Not recorded)	6	12	136	11
July 13–17	Faries Park and ½ mile below	4	15	302	20
Aug. 24	Faries Park	4	12	82	7
Oct. 16	Nelson Park Beach	3	6	270	45
Dec. 11	Nelson Park Beach	6	24	829	35

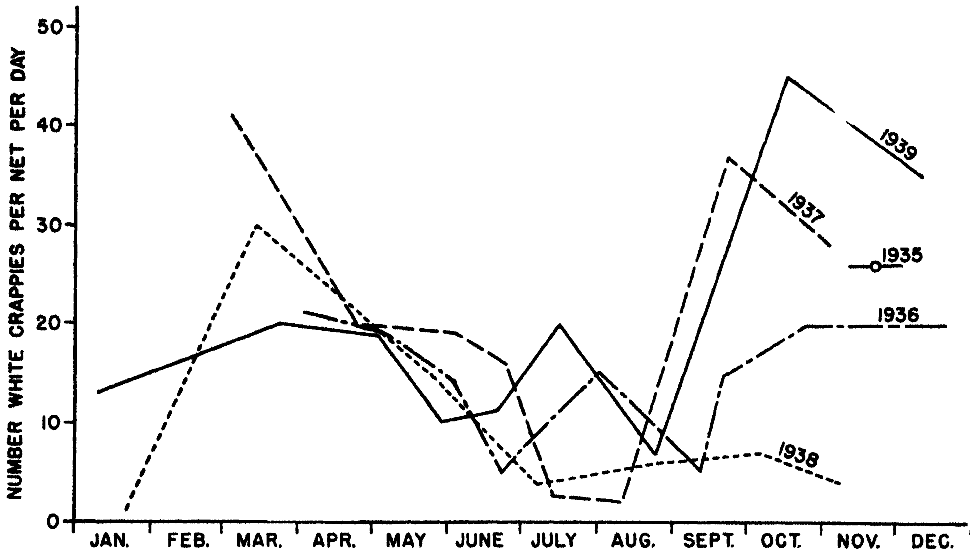


Fig. 4.—Seasonal variation in the rate of capture of Lake Decatur white crappies in inch-mesh hoop nets in the years 1935–1939.

rates of capture of the two species at different times of day and from week to week.

Seasonal Variations

Ordinarily the Lake Decatur crappies were more readily trapped in fall, winter, and spring than in summer. They were least readily trapped from about mid-July to late September, table 4 and fig. 4. The more noticeable departures from this trend include comparatively good catches in July, 1936, and July, 1939, and comparatively poor catches in January, October, and November, 1938. To some extent the wide fluctuations in catch rate at Lake Decatur may have resulted from lack of uniformity in sampling procedure. Thus, number of nets in use, number of days of operation, manner of setting, and occasional shifting of the nets from the Faries Park area to other places on the lake were all variables that might have affected the catch. All of the sampling in 1937 and 1938 was done in the Faries Park area, with the exception of the August collection in 1937 and the January collection in 1938. Summer mortality of crappies, discussed in the section "Size and Age Distribution," may have contributed to the poor summer net fishing at Lake Decatur.

Hoop-net sampling at Lake Glendale, Pope County (unpublished data), has shown similar seasonal trends in catchability of the bluegill, *Lepomis macrochirus*, and the largemouth bass, *Micropterus salmoides*. Lake Glendale netting operations were carried on at specified stations, and sets were duplicated the year round.

According to statements of commercial fishermen on the Illinois River, carp and buffalo also are trapped with difficulty in the summer months.

Species Variations

Differences in behavior patterns of black crappies and white crappies are suggested by differences in rates of capture of the two species.

Catch Rates at Night and During Day.—A hoop-netting experiment (results unpublished) carried on by Dr. David H. Thompson in 1931 at Meredosia Bay, one of the large bottomland lakes along the Illinois River, suggests the presence of a daily rhythm in crappie movement. The hoop nets were raised, emptied, and reset twice daily at the approximate hours of 6 A.M. and 5 P.M. on 25 different days during the period of June 24 through August 17. Nets were set within about 150 feet of the

Table 5.—Catches of white crappies and black crappies in morning and evening raises of 1-inch-mesh hoop nets. Data from an unpublished study made by David H. Thompson at Meredosia Bay, near Meredosia, Illinois, summer of 1931.*

Date	Number of Nets	Number of White Crappies		Number of Black Crappies	
		6 A.M. Raise	5 P.M. Raise	6 A.M. Raise	5 P.M. Raise
June 24	10	373	196	527	183
June 30	6	127	46	169	25
July 1	6	138	51	247	27
July 7	6	136	90	103	14
8	6	79	63	74	14
9	6	84	64	31	28
10	6	44	84	10	3
July 14	4	132	58	256	64
15	4	182	45	418	16
16	4	162	42	332	11
17	4	221	50	364	21
July 21	4	130	40	821	51
22	4	259	98	1,311	158
23	4	120	69	529	56
24	4	316	56	1,002	63
July 28	4	45	17	83	19
29	4	25	6	73	14
July 31	6	140	35	297	41
Aug. 4	4	49	9	32	4
Aug. 11	4	38	65	11	30
12	4	57	46	37	9
13	4	68	77	63	15
14	4	64	46	32	10
17	6	74	23	64	3
Total	—	*3,063*	*1,376*	*6,886*	*879*

* Horizontal broken lines set off raises made in the same locations. Fishing was carried on in nine different parts of the lake during this experiment.

Table 6.—Rates of capture of white crappies and black crappies in short periods of fishing with 1-inch-mesh hoop nets. Data from an unpublished study made by David H. Thompson at Meredosia Bay, near Meredosia, Illinois, summer of 1931.

Net Station	Period of Fishing	Total Net-Days	Number of Fish		Catch per Net-Day	
			White Crappies	Black Crappies	White Crappies	Black Crappies
A	June 24	10	569	710	60	71
B	June 30–July 1	12	362	468	30	39
C	July 7–10	24	644	277	27	12
D	July 14–17	16	892	1,482	56	93
E	July 21–24	16	1,088	3,991	68	249
F	July 28–29	8	93	189	12	24
G	July 31	6	175	338	29	56
H	Aug. 4	4	58	36	15	9
I	Aug. 11–17	22	1,134	274	52	12

shore where the water was about the depth of the nets or shallower. The location of the nets was changed at weekly intervals.

The experiment showed that except on a few dates both species entered the nets in larger numbers between the hours of 5 P.M. and 6 A.M. than in the remaining hours of the day, table 5. During the whole experiment the raises at 6 A.M. yielded approximately twice as many whites and eight times as many blacks as the raises at 5 P.M. It is not known whether fish in the 6 A.M. raises had entered the nets during the hours of total darkness. It is presumed, however, that many had.

The following are offered as explanations of the larger catches at night: (1) The fish possibly were more vulnerable to capture during the hours of darkness when less able to avoid the nets or see their way of escape if once captured. (2) They possibly were more concentrated near shore during all or part of the night period (this explanation implying in-shore and off-shore movement, perhaps for purposes of feeding). (3) They possibly were more actively engaged in swimming at night than during the day. It is not believed that the longer night period, 13 hours as compared with 11 hours during the day, could fully account for the differences observed.

A striking difference between white crappies and black crappies in the degree of expression of this day-night catchability was found. Morning raises yielded more blacks than whites, evening raises more whites than blacks, table 5.

Catch Rates by Weekly Periods.—Additional evidence that white crappies have different behavior patterns from those of black crappies is shown by comparing catch totals by 1-week periods. In tables 6 and 7, catch totals of white crappies and of black crappies are shown for hoop-net fishing carried on at Meredosia Bay in 1931 and at Lake Chautauqua at various times in the period 1931–1945. These tables show that in both lakes the ratios of numbers of these two species often fluctuated widely, from week to week, sometimes in spite of large catches of both species. It must be emphasized, however, that the netting sites were changed at frequent intervals at both Meredosia Bay and Lake Chautauqua and

Table 7.—Fluctuations in numbers of white crappies and black crappies collected during short periods of fishing with 1-inch-mesh hoop nets at Lake Chautauqua, near Havana, Illinois, 1931–1945.

Date of Collection*	Number of White Crappies	Number of Black Crappies
1931		
June 11 13	48	205
1934		
April 4–May 4	6	1,303
1935		
Nov. 14-25	5	34
1936		
Feb. 12 April 12	3	18
Sept. 1–6	134	45
Sept. 7 13	455	241
Sept. 14–20	117	119
Sept. 21 27	158	141
Sept. 28 Oct. 4	465	179
Oct. 5-11	160	305
Oct. 12–18	208	465
Oct. 26 Nov. 1	24	145
1937		
March 29 April 5	113	665
April 26 30	74	134
May 4-5	17	21
1940		
March 21 27	1,803	673
March 29 April 4	3,281	2,150
April 5 11	516	935
April 12 18	1,444	412
April 19-25	992	846
April 26 May 2	281	307
May 10 16	618	373
May 17 23	2,772	1,267
May 24–30	279	196
1941		
April 7–14	1,177	1,068
May 29-June 4	24	264
Nov. 9 10	57	160
1942		
May 4-14	586	597
July 10 11	20	253
1943		
April 27 29	128	50
May 27 June 2	266	128
Sept. 17 18	230	3
1945		
April 21–23.	356	119
Total	*16,817*	*13,821*

* The number of net-days per period was not uniform throughout the study because of variation in length of periods and in number of nets used.

that differences in catch ratios may have been due to differences in concentrations of the two kinds of fish at the various netting stations. It might be speculated further that the whites and blacks school by individual species and that the number of each species caught during any 1-week period was determined principally by chance, that is, by the number of schools encountering the nets. Another possible explanation for the unstable catch ratios is that, as a result of environmental changes, for example, changes due to weather, the two species behaved differently and reacted differently to hoop nets.

FOODS

The published observations of Forbes & Richardson (1920), Pearse (1919), Ricker & Lagler (1942), Eddy & Surber (1947), and Johnson (1945) show that the principal foods of both white crappies and black crappies are small fish, aquatic insects, and small crustaceans. The relative importance of the three types of food mentioned have differed considerably in the crappie collections studied by different men, possibly in consequence of local differences in food supplies or in the time of year collections were made.

Only limited observations were made on the feeding habits of white crappies in Lake Decatur. In the summer of 1936, the winter of 1936–37, and the spring of 1937 the stomachs of the white crappies from this lake were often found to be filled with small gizzard shad, *Dorosoma cepedianum*, which were abundant at that time.

Some findings of a previously unpublished study of the food of Rock River crappies made for the Natural History Survey by the late R. E. Richardson are shown in table 8.

Table 8.—Percentages of foods (by volume) found in the stomachs of 64 white crappies and 190 black crappies from the Rock River system, 1924–1927. Data from an unpublished study by R. E. Richardson.

KIND OF FOOD	PERCENTAGE OF FOOD BY VOLUME	
	White Crappie	Black Crappie
Terrestrial insects.....	0 60	0.71
Aquatic insects....	34 96	45 65
Other aquatic invertebrates...........	1 17	0 47
Fishes	57 88	44.07
Animal matter unclassified..	5.06	8.72
Vegetable matter......	0 12	0.04
Organic matter mixed. .	--	0.16
Earth and mineral matter.	0.21	0 18
Total.	*100 00*	*100.00*

MIGRATIONS

By means of tagging operations carried on in a number of the large rivers and adjoining lakes in various parts of Illinois, Thompson (1933) found that both white crappies and black crappies are given to travel. He observed upstream and downstream movements, and concluded that the movements of the crappies, as well as the other species tagged, are random or haphazard. Four white crappies were recaptured upstream, 3.5, 8, 16, and 18 miles from tagging points; three others were retaken downstream, 1, 2, and 3 miles from tagging points. The distances of travel were similar for the black crappies except that one black crappie was caught 77 miles upstream.

There is little if any indication from Thompson's study that these movements of crappies were related to spawning.

Eschmeyer (1942) found that six tagged crappies (kind not specified) in Norris Reservoir were retaken at distances of 0 to 18 miles from points of tagging.

Miller & Bryan (1947) reported recapture of nine tagged white crappies at distances of 0.1 to 1.2 miles from the point of tagging in Wheeler Reservoir, 6 to 41 days after the date of tagging.

REACTION TO CURRENT

At Lake Springfield, Sangamon County, in May, 1941, white crappies were observed concentrated in front of an 8-by-10-foot wire screen fastened to a culvert that delivered a large volume of water into the lake from an electric power plant. The water coming from the culvert entered the lake at the lake level, that is, there was no fall. The crappies could be caught

readily with a dip net. In 11 dips with a circular net measuring 2 feet across, 60 white crappies were taken. These measured 5 to 9 inches in length, averaging about 6 inches. Positive reaction to strong currents is, of course, well known for a number of species of fishes. No temperature readings were obtained at the culvert outlet.

REPRODUCTION

Biologists regard a knowledge of the facts of fish reproduction as of special importance in their efforts to bring about population increases in certain species of fish. Both kinds of crappies in Illinois waters show a strong tendency to reproduce in adequate numbers, so that artificial aids to reproduction have so far not seemed necessary. It is possible that a knowledge of the facts of crappie breeding may prove to be of use in the development of methods of limiting already overcrowded populations.

Sexual Maturity

Sexual maturity in Illinois white crappies is reached at the end of the second or third year, that is, at an age of about 24 or 36 months. There is no indication that white crappies in Illinois ever spawn when 1 year old, although spawning at 1 year has been observed in Texas black crappies (Harper 1938). Only about a third of the white crappies hatched at Lake Chautauqua in the spring of 1938 appeared to be approaching maturity as 2-year-olds (ages determined by scales and by size distribution) when specimens were examined in May, 1940. In a sample of 127 2-year-old females examined on May 16, dissections showed that the ovaries of only 40 contained well-developed (large) eggs. The ovaries of the other 87 females of that age group were still in an immature stage and it was believed that none of this group of 87 2-year-olds would reach maturity during the 1940 spawning season. The 40 mature females averaged 6.2 inches total length, while females in which the eggs were undeveloped averaged 5.8 inches.

Fully mature, 2-year-old white crappies (ages determined by scales) were captured at Lake Decatur on June 3–5, 1937; included were ripe individuals of both sexes. These fish averaged approximately 2 inches longer than the ones from Lake Chautauqua that did not seem to be maturing as 2-year-olds.

Among 2-year-old white crappies examined by Eschmeyer, Stroud, & Jones (1944) from one of the reservoirs of the Tennessee River, some were mature and others were not.

The smallest ripe white crappie observed in Illinois was a female of 5.6 inches, total length, caught on May 20, 1941, at Lake Springfield. The scales of this fish did not show clearly whether its age was 2 or 3 years.

Breeding Coloration

The coloring of male and female white crappies is identical except during and near the spawning season, when the breeding males typically turn darker, while the females typically remain unchanged in color. The darker coloring of the male, darker in some individuals than in others, is most noticeable on the sides of the head, chin, and breast, and to a lesser extent on the sides of the body. It begins to appear in April, reaches maximum intensity about the last of May, and is lost in most males by the last of June. The disappearance of the breeding color seems to take place gradually, and some males retain remnants of the breeding pigmentation well into July.

The following tests were made to discover the degree of error in using breeding color as a basis for sex recognition in spring collections of white crappies. The fish were first sorted as to sex on the basis of color; then they were opened and their reproductive organs were examined. In these tests, it was found that sex was usually guessed correctly, but that errors were sometimes made in fish large enough to be sexually mature as well as in small fish which may have been immature.

At Lake Decatur, 100 specimens were examined in the period May 17–20, 1939. Among 19 white crappies first judged to to be males by their dark pigmentation, dissection showed 18 males and 1 very darkly pigmented female. Among 81 judged to be females by the absence of dark pigmentation, dissection showed 2

males and 79 females. The true ratio was 20 males and 80 females, instead of 19 males and 81 females.

At Lake De Pue on April 26, 1942, 3 males and 12 females were correctly sexed by means of breeding color.

At Lake Springfield on May 20, 1941, a group of 36 white crappies classified as females on the basis of color included 7 light-colored males. Fish showing male pigmentation were not dissected.

Light-colored males in the tests were of the following total lengths: at Lake Springfield, 6.3, 6.3, 6.5, 6.6, 7.2, 7.2, and 8.4 inches; at Lake Decatur, 8.1 and 8.7 inches; and, at Lake Chautauqua, 8.7 and 9.8 inches. Some of the males, though possibly not all of them, were large enough to be sexually mature. The one female caught at Lake Decatur that was so dark it was mistaken for a breeding male was 10.2 inches long.

Spawning Season

After examining market specimens at Havana, Illinois, Forbes & Richardson (1920) gave May as the spawning time of the white crappie in this state. White crappies were observed on nests at Lake Springfield on May 26, 1941 (Hansen 1943). The black crappie evidently nests about the same time as the white. Forbes & Richardson reported that the black crappie spawned in May at Havana in 1898. Richardson (1913) found a nesting black crappie at Havana on May 2, 1911.

Frank Rhodes of Carlinville, Illinois, stated on the basis of several years of observation that crappies (kind not specified) nest at nearby Beaverdam Lake in May and again in September. September nesting has not been reported elsewhere and it is possible that the behavior of nesting was observed in September when nesting was not actually taking place.

Eddy & Surber (1943) reported that in Minnesota the white crappie spawns in late spring and early summer, and that the black crappie usually spawns in May and June but that spawning has been observed in July. Pearse (1919) found nesting black crappies at Madison, Wisconsin, on May 20, 1916.

Eschmeyer & Smith (1943) found that spawning of crappies might be delayed or prevented if the fish were kept at continuously low water temperatures.

The approximate spawning date of the white crappie in Illinois is further indicated by occurrence of ripe and unripe gonads, table 9. A ripe condition of the gonad was detected by squeezing, with moderate pressure, on the sides of the fish in the region just above the vent. Males were classified as ripe if they yielded milt, and females if they yielded runny, sticky, translucent eggs. An individual of either sex was not considered ripe if hard squeezing was required to obtain eggs or milt.

Squeezing tests indicate that May and June are perhaps equally important months for white crappie spawning in Illinois, and that the height of the spawning season usually falls in late May or early June. Field records noting the occasional finding of a ripe male or female show that some spawning may occur in July. Ripe male white crappies have been found as early as May 16 and as late as June 24, while ripe female white crappies have been found as early as May 6 and as late as July 13.

Changes in Ovary Size

Enlargement of the ovaries of white crappies has been observed in Illinois from early April through June or early July. This enlargement results from enlargement of the eggs. Squeezing tests indicate that some eggs ripen in advance of others and occasional dissections show that eventually the ovary contains practically a solid mass of ripe eggs. Close attention has not been paid to the time of year when the ovary starts to enlarge in preparation for a new spawning season. However, the occurrence of the reduced or post-spawning stage has been noted as follows at Lake Decatur: July 3–5, 1936, 16 females had reduced ovaries while 9 females still had more or less enlarged ovaries; July 31–August 3, 1936, all of the 39 females examined had reduced or immature ovaries, table 9. Presumably the July 31–August 3 collection included some mature females which had completed the spawning cycle.

Even though collecting was not continuous throughout the spawning period, the fact that the writer failed to observe a

Table 9.—Counts of sexually ripe[1] male and female white crappies in central Illinois.[2] All fish caught in 1-inch-mesh hoop nets, except as shown.

Date of Collection	Place	Males			Females		
		Number Examined	Number Ripe	Per Cent Ripe	Number Examined	Number Ripe	Per Cent Ripe
May 28, 1936[3]	Sangamon River, Decatur	5	1	20	4	1	25
May 29–June 4, 1936	Lake Decatur	39	1	3	63	21	33
July 3–5, 1936	Lake Decatur	17	0	0	28[4]	0	0
July 31–Aug. 3, 1936	Lake Decatur	43	0	0	39[5]	0	0
June 4, 1937	Lake Decatur	79	45	57	123	54	44
June 24, 1937[6]	Lake Decatur	—	—	—	81	—	5-10
May 28, 1938	Lake Decatur	—	—	—	15	1	7
May 17–20, 1939[3]	Lake Decatur	19	5	26	57	15	26
May 16–29, 1940	Lake Chautauqua	32	8	25	106	10	9
May 14–20, 1941	Lake Springfield	—	—	—	10	2	20

[1] Fish were designated as ripe if moderate pressure around vent resulted in extrusion of milt or sticky, translucent eggs.
[2] Lake Chautauqua, Mason County; Lake Decatur and Sangamon River, Macon County; Lake Springfield, Sangamon County.
[3] Examination of anglers' catch.
[4] Ovaries still noticeably enlarged in 9 females, ovaries much reduced in 16 females, classification intermediate or uncertain in 3 females.
[5] Ovaries much reduced or immature in all females.
[6] Some ripe males were found in this collection, but no complete count of ripe males was made. Of the total number of females taken, 81 were examined and the percentage of females ripe (5 to 10 per cent) was estimated immediately after the examination.

single empty ovary in a mature-size white crappie at the height of the spawning season in May and June is an indication that only part of the ripened contents of the ovary is voided in a single spawning act. Whether the white crappie female lays eggs in more than one nest was not learned.

The finding, in the latter half of the spawning season, of many white crappie females with enlarged but somewhat flabby ovaries, each containing large numbers of eggs, all opaque and unripe, suggests to the writer that an undetermined number of eggs, perhaps a considerable number, may be absorbed rather than laid.

Of another centrarchid, the bluegill, James (1946) reported, "Spawning appears to be intermittent during the summer months, but upon its completion resorption of the remaining eggs takes place. . . . . Evidence of resorption could be seen in sectioned materials from late August until December."

As a general rule, the enlargement of the crappie ovary at or near spawning time is not sufficient to produce a noticeable bulging of the sides of the fish. In the only instance the writer observed in which a large percentage of the female crappies had sides that bulged with eggs, the bulged condition was decidedly more prevalent in late April, in advance of the spawning season, than in late May, near the height of the spawning season. This observation was made on white crappies of about 11 inches and larger caught in hoop nets at Lake Chautauqua during the spring of 1940.

Nesting Habits

In common with all other centrarchids, crappies of both species guard their eggs and, like certain others, they do not invariably fan out nests. There is little uniformity in the sites they select.

Six white crappies, apparently nesting, were observed by the writer at Lake Springfield on May 26, 1941 (Hansen 1943). The six crappies, 6 to 7 inches in length, were in water 4 to 8 inches deep along an undercut sod bank of red clay. They were spaced 2 to 4 feet apart and were well concealed from the casual passer-by by the overhanging bank and by a

small elm tree that was growing in the water near the bank.

All six fish were moving the pectoral fins as if fanning eggs. They had not excavated nests, perhaps because the lake bottom at this place was hard and free of loose sediment. Close-range examination of the crappies and their surrounding territory failed to reveal eggs near four of the fish. Visible near one of the others were a few hundred eggs attached to dead blades of lawn grass and grass roots dangling in the water from the edge of the overhanging sod bank. The eggs were not more than 2 inches under the surface of the water; the fish guarding these eggs was actually below them. Guarded by another fish were at least a thousand eggs attached to a 3-inch ball of elm roots. The eggs averaged 0.89 mm. (0.034 inch) in diameter.

In 1940, L. J. Hoggatt, Springfield fisherman, found a single white crappie nest under the floor of a boathouse at Lake Springfield about 100 yards from the site of the writer's 1941 observations. In this case a thin layer of silt had been fanned away from a circular area 5 or 6 inches across, exposing a sandy bottom.

In line with the observation made above that probably only a small proportion of the eggs are deposited at one spawning act, the Lake Springfield fish observed in 1941 were guarding only a small fraction of the number of eggs which a female crappie is capable of producing. A similar situation was found among crappies which had spawned in a Washington, D. C., aquarium (Anonymous 1919). While egg counts have not been made on white crappie ovaries, Ulrey, Risk, & Scott (1938) made observations on numbers of eggs in black crappie ovaries which suggest the probable egg production of the white crappie. Their count showed from 27,000 to 68,000 eggs per black crappie female; the number of eggs depended on the age or size of the female examined. Eddy & Surber (1947) stated that a black crappie of 1½ pounds may have as many as 140,000 eggs in its ovaries.

There are similarities between nesting of the white crappies at Lake Springfield and published accounts of nesting of black crappies. The tendency of crappies to place their nests near some sort of vegetation is mentioned in various descriptions. In all cases where eggs of either species have been found they were attached to plant material. Considerable variation has been observed in depth of the water over the nests (from a few inches to 20 feet), in kinds of substrata (mud, clay, rock, sand, gravel, and concrete), and in distance of the nests from the shore.

At Havana, Illinois, Richardson (1913) found a black crappie nest hollowed out under the leaves of a water parsnip in water 10 inches deep. Other plants surrounding the nest included smartweed and bog rush. Most of the eggs were seen on the leaves of the water parsnip 2 to 4 inches above the bottom of the nest; others adhered to fine roots in the bottom of the nest.

Pearse (1919) found a number of black crappie nests at Lake Wingra, Madison, Wisconsin, along the edge of an undercut clay bank in water 2 feet deep; the nests were adjacent to an unidentified, submerged, aquatic plant.

At Lake Maxinkuckee, Indiana, Evermann & Clark (1920) found black crappies nesting on the sand and gravel bars at depths of 8 to 10 feet and shallower, the nests usually surrounded by chara. They gave the diameters of the nests as 8 to 9 inches.

Eddy & Surber (1947) wrote of the spawning of black crappies in Minnesota: "The nests are often close together and are sometimes built on bottoms that are softer and muddier than those usually chosen by members of this family."

An instance of crappie spawning at the Bureau of Fisheries Aquarium at Washington, D. C., is described in the magazine *Aquatic Life* (Anonymous 1919). The pair of fish involved had been at the aquarium for a number of years. Spawning occurred some time during the night of May 25. An estimated 6,000 eggs, some practically at the surface, were attached to algae, which formed a dense growth on the stones covering the steeply inclined back wall of the tank. The first young were seen on the morning of May 28 and all fertile eggs had hatched by May 31. As pointed out by Breder (1936), the *Aquatic Life* reference to the fish as a crappie rather than as a calico bass, or any other name for the black crappie, suggests

that the white crappie was probably the species under observation.

Nelson (1941) mentions that crappies (species not identified) spawned on cowlot manure straw in federal hatchery ponds at Elephant Butte, New Mexico. In letters to the writer, Mr. Nelson has given further details on crappie nesting both in these hatchery ponds and in nearby Elephant Butte Lake. In the ponds he observed that nesting was carried on in the open at water depths of 2½ to 5 feet; that the crappies nested in colonies; that the nests were scooped out, though not as deeply as those of other sunfishes; that the eggs were attached to straw (from the fertilizer), to "chara or other moss," but that the crappies sometimes spawned where there was nothing whatever for egg attachment; that the crappies did not use the gravel beds that were available in the ponds. Nelson observed quite different nesting sites at Elephant Butte Lake, where in clear water he had seen crappies nesting at depths of 10 to 20 feet, "on rocks, boulders, submerged brush and trees, but never on sand or gravel bars or beaches." Presumably he referred to white crappies, as Greenbank (1937) found no black crappies in Elephant Butte Lake during his net-fishing studies.

Over a period of 6 to 7 years, the writer interviewed a considerable number of persons in an effort to gather more information on spawning habits of crappies in Illinois. Only five persons among those questioned had observed the nesting of crappies. Mr. Hoggatt's observation on nesting at Lake Springfield has already been mentioned. None of the other four observers knew which species of crappie had been observed.

At Scott's Pond, near Mount Zion, Illinois, Paul S. Smith of that place observed a 12-inch crappie guarding a nest situated on the submerged top of a concrete retaining wall for an earth dam. The nest was somewhat concealed by surrounding vegetation.

An engineer at Staley's pumping station on Lake Decatur believed he had seen crappies in the act of spawning along the submerged sloping concrete facing at the foot of the Baltimore & Ohio Railroad embankment 15 feet from the pumping station. This concrete facing supported a growth of filamentous algae to which the engineer believed the eggs were attached. The situation in this instance was similar in important respects to that at the Washington Aquarium.

Frank Rhodes said that crappies at Beaverdam Lake spawned among aquatic plants along a shaded stretch of shore in water 1 to 2 feet deep. The fish had fanned away sediment to expose fine gravel or clumps of roots of nearby trees.

Anthony Kuderka of Taylor Springs, Illinois, saw crappie nests at Taylor Springs Lake on various occasions. He observed the nests in clear water near shore at a depth of about 2 feet. He described the nests as less deeply excavated than those of bluegills and always located near water plants.

As yet there have been no descriptions of nest building operations of crappies, nor has anyone described their mating behavior. Little is known about the behavior of the fish while guarding the nests. More information is needed on numbers of eggs deposited in nests and on losses of eggs because of predation or disease. The fact that nesting of crappies is not more often observed may be due to a preference for nesting sites within the concealment offered by water weeds, overhanging trees, undercut banks, and man-made structures. The turbid condition of most Illinois lakes in the spring is a hindrance to observation, and it is possible that the crappies usually nest in deeper water than that selected by the more frequently observed members of the sunfish family.

Sex Ratios

Sex ratios calculated for white crappies studied in Illinois varied with age and length of the fish, season of take, and method of capture.

Sex Ratios and Differential Survival of the Sexes.—In the Lake Decatur net samples, table 10, most of the young crappies were males and most of the older ones were females. Apparently, equality in sex ratio was present only from about the end of the second to about the end of the third year of life. It is not known to what extent the unbalanced sex ratio in these young crappies may have been the result of selectivity of the hoop nets.

Taken at face value the figures showing predominance of males among the two youngest broods could mean either that more males than females were hatched in these particular broods, or that the young females were subject to heavier early mortality than the young males.

Among older fish, on the other hand, the predominance of females over males was so great as to leave little doubt that after about the third year males die off much faster than females.

While it appears in table 10 that sex ratios shift as the fish become older, the possibility must be kept in mind that some broods may start out with a predominance of males and other broods with a predominance of females.

Table 10.—Ratios of males to females in Lake Decatur white crappies of different ages. All collections made with 1-inch-mesh hoop nets.

Age of Brood at Midpoint of Study, Months*	Brood	Period of Study: July 31, 1936–July 16, 1937 (11½ Months)	Period of Study: Nov. 4, 1938–Jan. 9, 1939 (2 Months)	Number Examined of Both Sexes	Males	Females	Males per 100 Females
18	1937		x	126	78	48	163
20	1935	x		557	321	236	136
31	1936		x	89	38	51	74
32	1934	x		783	350	433	81
44	1933	x		179	63	116	54
60	1932	x		12	0	12	0
73	1931	x		9	0	9	0
83	1930	x		3	1	2	50

* Brood ages were computed from an assumed June 1 hatching date.

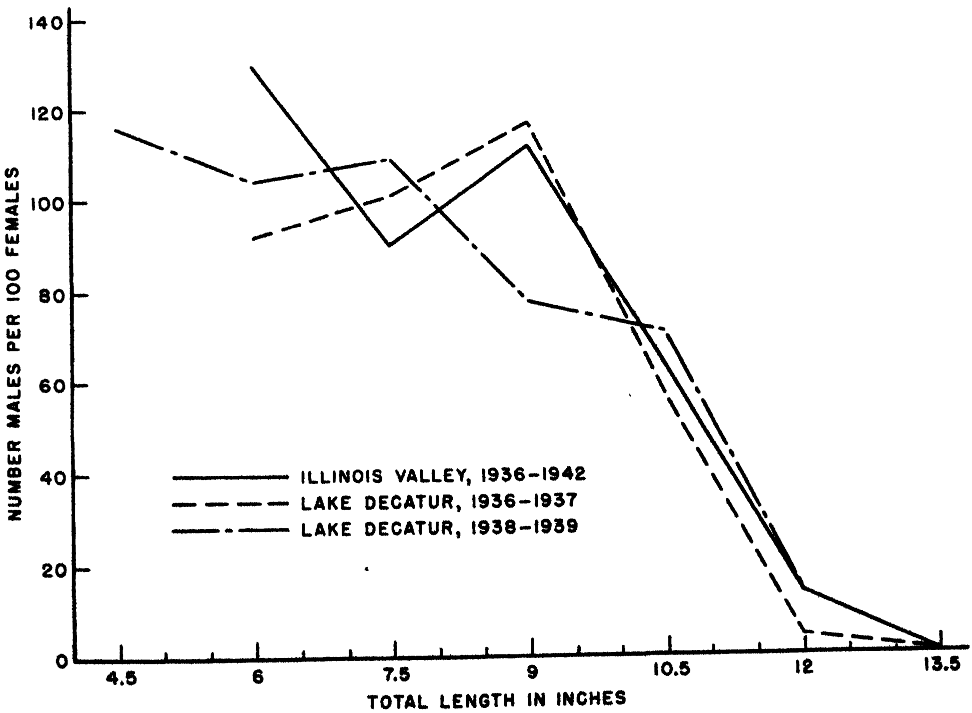


Fig. 5.—Changes in sex ratio of white crappies of different length classes. Data from Lake Decatur and from bottomland lakes of the Illinois River valley.

Corresponding somewhat with a change in sex ratios among crappies of different age classes is a change in sex ratios among crappies of different size classes. Collections from Lake Decatur and the Illinois River valley show a fairly well-defined

Table 11.—Ratios of males to females in white crappies of various lengths, as determined by observations on fish collected at Lake Decatur and in bottomland lakes of the Illinois River valley. All collections made with 1-inch-mesh hoop nets.

Total Length Class, Inches*	Lake Decatur						Illinois River Valley		
	July, 1936, to July, 1937			Nov., 1938, to Dec., 1939					
	Males	Females	Males per 100 Females	Males	Females	Males per 100 Females	Males	Females	Males per 100 Females
4½	0	1	—	103	89	116	1	0	—
6	25	27	92	366	351	104	43	33	130
7½	132	131	101	470	430	109	75	83	90
9	446	380	117	219	280	78	139	124	112
10½	190	331	57	59	83	71	64	102	63
12	1	25	4	6	45	13	6	46	13
13½	0	6	0	0	14	0	0	4	0
15	—	—	—	—	—	—	0	1	—

* Class center is indicated; the 4½-inch class includes fish of 3.8 through 5.2 inches total length, the 6 inch class includes fish of 5.3 through 6.7 inches.

Table 12.—Ratios of males to females in white crappies taken in different months, as observed in entire hoop-net catches at Lake Decatur.

Date of Collection	Number of Specimens	Males	Females	Males per 100 Females
1936				
May 29–June 4	100	37	63	59
July 3–5	45	17	28	61
July 31–Aug. 3	82	43	39	110
Sept. 8–22	88	52	36	144
Oct. 24–27	228	119	109	109
Dec. 21	295	153	142	108
1937				
March 1–4	297	150	147	102
April 24	115	41	74	55
June 3–5	225	91	134	68
June 24	133	52	81	64
July 10–16	84	38	46	83
1938				
Nov. 4–11	73	37	36	103
1939				
Jan. 9	153	87	66	132
March 24	315	156	159	98
May 3	146	75	71	106
May 29	118	39	79	49
June 20	135	70	65	108
July 13–17	313	165	148	111
Aug. 24	80	44	36	122
Oct. 16	266	134	132	102
Dec. 11	817	402	415	97
Total	*4,108*	*2,002*	*2,106*	*95*

shift in sex ratios from a preponderance of males among small crappies to a preponderance of females among large ones, table 11 and fig. 5.

In the longear sunfish, *Lepomis megalotis peltastes,* studied by Hubbs & Cooper (1935), the age-sex ratio trend was similar to that of the white crappie of Lake Decatur, although the preponderance of females among the older longear sunfish was restricted to fish in the fifth summer. In the green sunfish, *L. cyanellus,* studied by Hubbs & Cooper (1935), in the bluegill, *L. macrochirus,* studied by Schoffman (1938), and in the redear sunfish (western shellcracker), *L. microlophus,* studied by Schoffman (1939), collections of older fish tended to be predominantly male.

Seasonal Variations in Sex Ratios of Fish Taken in Hoop Nets.—In the white crappies of Lake Decatur, the date of sampling appeared to have a bearing on the calculated sex ratio, table 12 and fig. 6. In most fall, winter, and early spring collections, males were more numerous than females, while in most late spring and early summer collections males were less numerous than females. A drop in the relative numbers of males approximately paralleling that seen at Lake Decatur in the spring of 1939 was observed in the hoop-net samples at Lake Chautauqua in the spring of 1940, as follows: a sample of 152 white crappies caught April 24 and 25 showed a ratio of 127 males per 100 females, while a sample of 503 specimens taken May 22–28 showed a ratio of only 26 males per 100 females. This spring-summer scarcity of males might be expected to have been the result of the more prolonged involvement of the males with nest construction and guarding. However, reference to fig. 6 shows that in certain years the period of male scarcity at Lake Decatur was somewhat longer than the major spawning season.

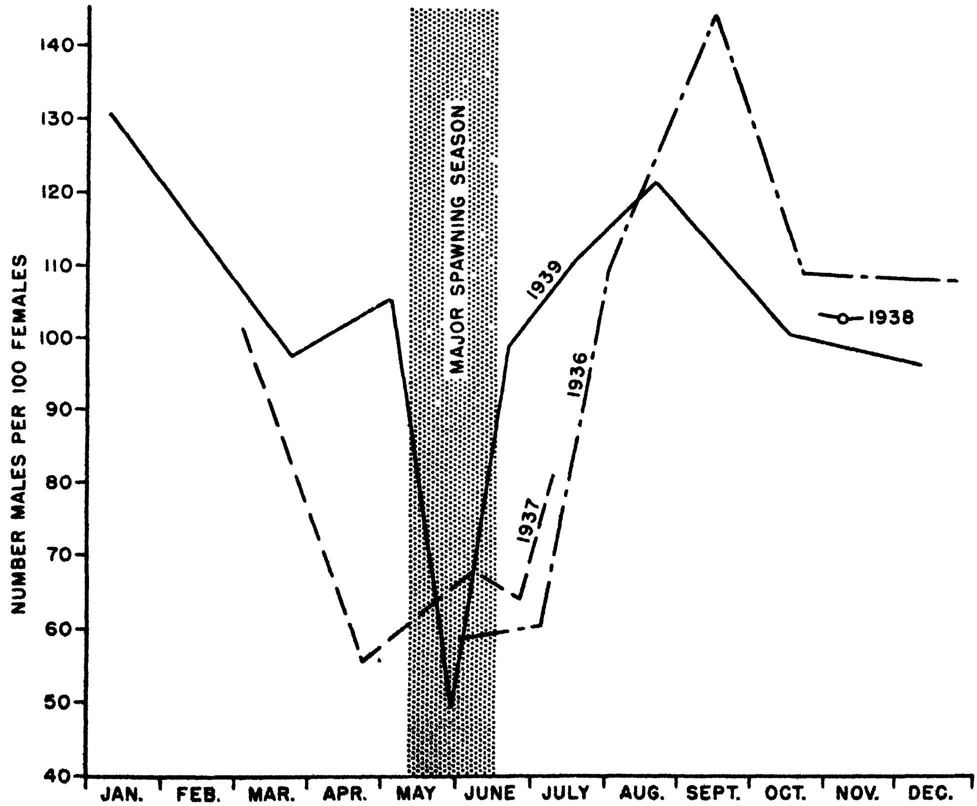


Fig. 6.—Seasonal variation in sex ratio for entire samples of white crappies collected during different years at Lake Decatur. Only one observation on sex ratio was made in 1938.

Because of the comparatively short life-span of broods, table 20, a new brood in the net catches generally made up an important percentage of the total sample. It is worth while to consider that, if the members of a new brood entering the net samples were predominantly one sex or the other, it would have an important effect on the sex composition of the catch as a whole. In the Lake Decatur sampling, second-year fish that first entered the net catches in 1936 and 1938 at ages of 13–17 months were predominantly male, table 10, a fact that may partially explain the predominance of males in some of the entire net catches recorded in table 12. When a preponderance of females appears in collections made before another new brood is taken in the nets, it may be explained by a generally higher mortality rate among males that, data indicate, occurs some time after the middle of the second year.

Variations in Calculated Sex Ratios Resulting From Inadequate Sampling.—Inadequate sampling of fish populations may result in calculated sex ratios that fail to reflect the actual ratios in the populations sampled.

The following is an example of sex ratio variation which may arise even when the samples are large. At Lake Chautauqua in 1940, a striking difference in sex ratios was observed in samples taken on consecutive days: from a ratio of 14 males per 100 females on May 22 to a ratio of 51 males per 100 females on May 23. The locations of the nets were slightly different on the 2 days. The ratios were calculated from 308 fish the first day and 186 the second.

Sex Ratios in Two Hook-and-Line Catches.—Two observations on the sex of white crappies taken by hook and line were made at Lake Decatur. In each observation, males were much less numerous than females. On May 16, 1937, when scales and measurements were taken from 86 fish, it was estimated on the basis of breeding color that not more than 10 per cent of the 86 fish were males. On May 17–20, 1939, when 100 fish taken by anglers were sexed by gonad examination, the ratio was found to be 20 males to 80 females. In terms of number of males per 100 females, the sex ratios in these two catches were 11 and 25, respectively. A comparison of these ratios with those in table 12 will show that males were relatively scarcer in the anglers' catches than in any of the hoop-net catches at Lake Decatur.

DISEASE

The virus disease, lymphocystis, which appears in the form of white, granular, irregularly shaped lumps on the fins and bodies of fish, is the only disease known to occur commonly in Illinois crappies. It is found in both the white crappie and black crappie. An individual lump may cover as much as half a square inch of surface. In diseased fins the ends of the rays are sometimes missing, but the disease is not known to be fatal.

In counts made on fish from bottomland lakes in the Illinois River valley, lymphocystis was found in 1.4 per cent of the white crappies caught at Senachwine Lake, April 29, 1942, in 9.5 per cent of those caught at Lake De Pue, April 25–27, 1942, and in 19.5 per cent of those taken at Lake Chautauqua, September 17–18, 1943.

Some of the more recent investigations on lymphocystis are those of Nigrelli & Smith (1939) and Weissenberg (1939). Weissenberg has shown that the granular appearance of the lumps is due to enlargement of connective tissue cells.

ABNORMALITIES

The principal abnormalities observed in the white crappie relate to color and structure. Excessive slime production was observed in one locality.

Color and Structure

Usually the white crappie is easily distinguished from the black crappie on the basis of coloration. In the white crappie, the dark markings on the sides tend to form faint vertical bars or rings, while in the black crappie the dark markings produce an over-all mottling. It has been the experience of the writer to find rather frequent departures from these characteristic patterns in crappies smaller than 4 inches and larger than 10 or 11 inches. In many of these individuals, the dark markings are

not arranged in a manner that allows for positive species separation on the basis of color pattern alone.

Structural freaks among crappies have been observed by the writer a number of times. Many of these have the low angle of the mouth of the white crappie but the deep body and pigmentation of the black crappie. No observation was made on these specimens of the number of dorsal spines—usually different in white crappies and black crappies.

Humpbacks and foreshortened bodies, both resulting from disease of the spine, are conditions that have occasionally been seen in the white crappie as well as in other species of Illinois fish.

Excessive Sliminess

A heavy coating of mucus was observed by the writer in a large percentage of both white crappies and black crappies taken during fishing operations at Lake Chautauqua on April 10, 1941. The mucus tended to foam when the fish were emptied from the nets into the boat and made the fish unusually slippery in handling. This was the only occasion when excessive mucus was observed on crappies, but the condition was observed in the gizzard shad caught at Lake Chautauqua on September 17 and 18, 1943. The cause of this abnormal secretion of mucus was not determined.

Table 13.—Standard lengths and equivalent total lengths of white crappies. From a graph based on the measurements of 96 white crappies taken at Horseshoe Lake, Alexander County, Illinois, February 22–28, 1938. See section "Methods and Techniques" for definitions of standard length and total length.

Standard Length, Inches	Total Length, Inches
2 0	3 0
2.5	3 5
3 0	4.1
3.5	4.7
4 0	5 3
4.5	5.9
5 0	6 5
5.5	7 1
6 0	7.7
6.5	8.3
7 0	8.9
7.5	9.5
8.0	10 1
8.5	10.7
9.0	11 3
9.5	11.9
10 0	12 5

CONDITION OR PLUMPNESS

The coefficient of condition, K, representing relative plumpness was computed for white crappies from Lake Decatur and three other Illinois lakes by means of the formula:

$$K=\frac{\text{Weight in grams}}{\text{Standard length in centimeters}^3}\times 100$$

Length classes in this part of the paper are presented in terms of standard length rather than total length. Equivalent measurements in inches for standard and total lengths of white crappies are given in table 13. Original length and weight measurements in inches and pounds were converted to centimeters and grams as necessary for the computation of K values.

Seasonal Changes in K Values

This discussion, emphasizing seasonal variation in K values, is based on the collections made at Lake Decatur between April 3, 1936, and January 9, 1939. The build of the Lake Decatur crappies at the time of these observations appeared to be fairly typical of the build of crappies usually seen in Illinois; the seasonal changes in plumpness were not noticeable in the build of the fish. The average K values for members of various length classes appear for each collection date in table 14. The seasonal trends in average K values for the most abundantly represented length classes can best be followed in fig. 7. Some of the unevenness in the curves is quite obviously due to an insufficiency of specimens in some length classes.

That an average K value based on a small sample might not be truly representative of a length class is apparent from the wide spread of K values found among different individuals of a length class on the same date, table 15. The K values for two dates are shown in this table.

In describing seasonal changes in plumpness, it is necessary to make separate mention of the changes in large and small

Table 14.—Seasonal fluctuations in the coefficient of condition (K) in Lake Decatur white crappies of different standard length classes. Some of these data are plotted in fig. 7. Figures in parentheses represent numbers of specimens.

Date of Collection	Standard Length, Inches[1]								
	3	4	5	6	7	8	9	10	11
1936									
April 3	2.34 (3)	2.23 (101)	2.37 (85)	2.77 (77)	2.93 (42)	3.10 (16)	3.11 (1)	—	—
May 4–10	—	2.45 (25)	2.42 (15)	2.78 (26)	2.99 (12)	2.93 (2)	3.16 (4)	3.23 (2)	2.57 (1)
May 29–June 4	—	2.66 (5)	2.63 (17)	2.67 (37)	2.77 (25)	2.80 (12)	2.81 (2)	3.03 (3)	—
July 3–5	—	3.20 (2)	3.00 (11)	3.01 (26)	2.88 (3)	2.76 (2)	—	—	—
July 31–Aug. 3	—	2.65 (4)	2.87 (45)	3.03 (13)	3.04 (18)	2.57 (1)	—	—	—
Sept. 8–14	2.66 (2)	2.94 (1)	2.88 (3)	3.02 (11)	3.17 (8)	3.33 (4)	—	—	—
Sept. 22	—	—	2.62 (5)	2.98 (36)	3.06 (14)	3.04 (6)	—	—	—
Oct. 24–27	—	2.12 (1)	2.17 (2)	2.78 (21)	3.02 (95)	3.24 (107)	3.43 (11)	—	—
Dec. 21	—	—	2.79 (1)	2.96 (37)	3.17 (165)	3.29 (88)	3.48 (4)	—	—
1937									
March 1–4	—	—	2.08 (1)	2.84 (48)	3.03 (116)	3.26 (162)	3.37 (17)	3.00 (1)	3.26 (1)
April 24	—	—	2.31 (3)	2.57 (12)	2.90 (36)	3.09 (63)	3.31 (3)	—	—
May 16[2]	—	—	—	2.64 (4)	2.96 (44)	3.08 (33)	3.14 (5)	—	—
June 3–5	—	—	2.40 (3)	2.62 (26)	2.69 (75)	2.77 (103)	2.93 (16)	2.95 (2)	—
June 24	—	2.74 (4)	2.58 (1)	2.67 (9)	2.70 (37)	2.76 (71)	2.74 (12)	2.83 (4)	2.94 (2)
July 10–16	—	2.66 (6)	2.28 (2)	2.62 (11)	2.68 (34)	2.62 (35)	2.56 (2)	2.69 (4)	—
Aug. 6–14	—	2.67 (12)	2.71 (33)	2.76 (6)	2.86 (11)	2.91 (7)	3.06 (2)	—	—
Sept. 22	—	2.58 (12)	2.55 (149)	2.63 (47)	2.84 (5)	3.08 (3)	3.17 (1)	—	—
Nov. 3	—	2.41 (22)	2.43 (123)	2.61 (19)	2.97 (4)	3.17 (2)	—	—	—
1938									
Jan. 17–24	—	—	2.42 (11)	2.64 (1)	2.77 (1)	—	3.31 (2)	3.43 (2)	—
March 14	—	2.33 (24)	2.32 (112)	2.63 (41)	2.93 (12)	3.19 (13)	3.37 (8)	3.40 (1)	3.38 (1)
May 28	—	2.21 (35)	2.21 (40)	2.42 (8)	2.73 (3)	2.98 (4)	3.02 (8)	3.14 (2)	—
July 14	2.81 (1)	2.56 (21)	2.52 (6)	—	—	—	3.46 (1)	—	—
Aug. 25	2.79 (2)	2.48 (25)	2.66 (33)	2.78 (12)	2.78 (3)	3.29 (1)	2.96 (1)	—	—
Oct. 6	—	2.29 (1)	2.50 (18)	2.75 (39)	3.02 (8)	3.25 (3)	—	—	—
Nov. 4–11	—	2.41 (1)	2.35 (14)	2.73 (26)	2.93 (17)	3.08 (13)	3.18 (2)	3.11 (1)	—
1939									
Jan. 9	2.23 (1)	2.22 (5)	2.33 (14)	2.75 (45)	3.04 (64)	3.18 (21)	3.31 (3)	3.06 (1)	—

[1] Class center; for example, the 6-inch class includes fish of 5.6 through 6.5 inches in length.
[2] Sample obtained from anglers.

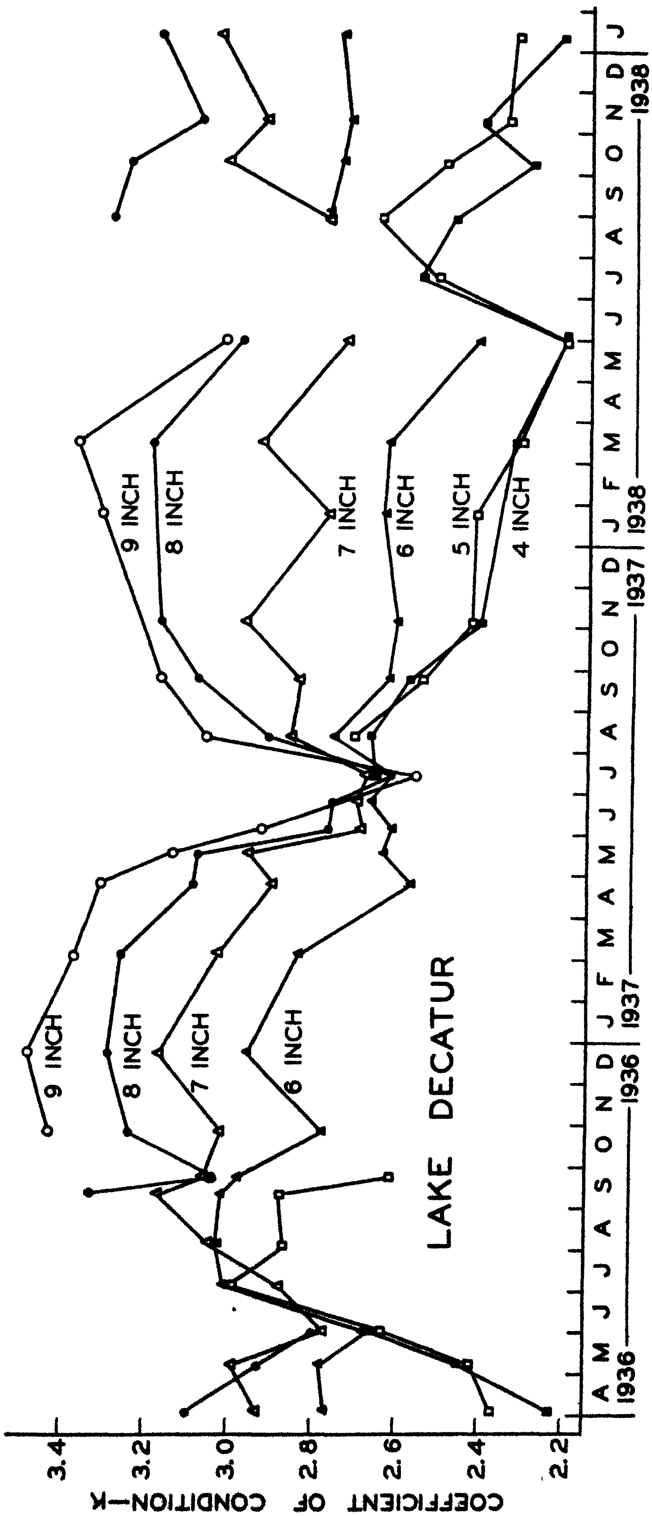


Fig. 7.—Seasonal fluctuations in the coefficient of condition (K) for white crappies of different length classes at Lake Decatur. (Data from table 14.)

crappies. White crappies over 7 inches (standard length) may be regarded as mature and those under 5 inches as immature. The seasonal changes may be summarized as follows:

Large sizes, crappies 7 inches standard length and smaller: Condition values increased rapidly through middle and late summer, reached a yearly peak in late fall or early winter, remained at a high level through the cold months, dropped sharply during the spring, and reached the lowest point in early summer.

Small sizes, crappies 5 inches standard length and smaller: Condition values increased from the middle of spring through early summer, reached a yearly peak in midsummer, fell off through late summer and fall, remained stationary through the cold months, and fell again through early spring.

Condition changes of crappies in the 6-inch class were approximately intermediate between changes described for fish of the two size classes discussed above.

Differences between large and small fish with respect to condition changes may be summarized as follows: The small crappies began to fatten earlier in the growing season than the large crappies, reached peak condition in midsummer rather than late fall or early winter, and lost condition in spring and again in late summer and fall, rather than only in the spring and early summer.

In fish that were less than 5 inches long at the start of the growing season and that grew to a length greater than 7 inches, the fall and subsequent spring changes in condition followed those described for the larger fish.

Increases in K values occurred only during the annual growing period.

Upward and downward trends in large and small fish described above for various seasons of the year have, for the most part, been based on observations made during 2 calendar years. The evidence of winter-to-spring drop in condition in large fish rests mainly on observations in 1937 when large sizes were abundant; winter observations were lacking for 1935–36, and large fish were scarce in the first half of 1938.

Fish of given sizes did not always show the same K values in corresponding months of different years. The 8-inch and 9-inch classes showed more uniformity in this respect than the smaller fish.

A tendency for large fish to have higher K values than small ones was observed in the smallmouth bass by Bennett (1938), in the largemouth bass by Thompson & Bennett (1939), and in the bluegill by Bennett, Thompson, & Parr (1940). Such a relationship was also found in the Lake Decatur white crappies but was unapparent or inconspicuous at certain times of the year—especially in June and July. The similarity of K values in all sizes of white crappies at that time of year may be ascribed to two things: (1) Late winter and early spring weight losses were relatively greater in large fish than in small ones (compare the changes in K values in the 6-inch to 9-inch classes from March to June, 1937) and (2) summer gains in K values started earlier in small fish than in large ones. Adequate data on the spread of K values are not available for June and July, 1938, because no collecting was attempted in June, and the July collection included only a few large fish.

A limited number of comparisons between K values of males and females of various lengths, table 16, indicates that the seasonal changes in condition occur in both sexes and that throughout the year K values tend to be a little higher in males than in females. Stroud (1948) found no important difference in plumpness between the sexes of black crappies in Norris Reservoir, Tennessee.

In black crappie collections made at several different times of year, Stroud (1948) did not find important differences in plumpness among four age categories or among size groups ranging from 4 to 12 inches. The failure of his data to show important differences is perhaps explained by the fact that most of his collecting was done in the spring, which, as indicated by observations at Lake Decatur, is a time of year when large and small crappies are of similar plumpness.

Changes in the average K value for members of various broods taken in the nets between early April, 1936, and early January, 1939, may be seen in table 17 and fig. 8. Broods represented in the nets by only a few specimens have been omitted from the table and graph. The longest

period of observation of any brood was about 2 years. A certain amount of resemblance may be seen between the curves in figs. 7 and 8. In general, the seasonal

Table 15.—Examples of the distribution of coefficient of condition (K) in white crappies of four size categories, 6–9 inches standard length, at Lake Decatur, March 1–4, and June 24, 1937. These dates were arbitrarily selected.

K Value	Standard Length* of Fish Collected, March 1–4, 1937				Standard Length* of Fish Collected, June 24, 1937			
	6 Inches	7 Inches	8 Inches	9 Inches	6 Inches	7 Inches	8 Inches	9 Inches
2.0	—	—	—	—	—	—	—	1
2.1	—	—	—	—	—	—	—	—
2.2	—	—	—	—	—	1	—	—
2.3	—	—	—	—	—	—	1	—
2.4	1	—	—	1	—	2	3	—
2.5	—	—	—	—	2	4	8	—
2.6	11	2	—	—	2	8	6	2
2.7	9	5	—	—	3	8	14	3
2.8	5	11	2	—	2	7	16	4
2.9	11	27	6	—	—	6	16	1
3.0	4	16	11	1	—	1	7	3
3.1	4	23	23	—	—	—	—	—
3.2	2	11	39	—	—	—	1	—
3.3	—	16	24	3	—	—	1	—
3.4	—	2	30	6	—	—	—	—
3.5	1	1	16	3	—	—	—	—
3.6	—	1	7	2	—	—	—	—
3.7	—	1	3	1	—	—	—	—
Total	*48*	*116*	*161*	*17*	*9*	*37*	*71*	*14*
Average K	2.84	3.03	3.26	3.37	2.67	2.70	2.76	2.74

* Class center; for example, the 6-inch class includes fish of 5.6 through 6.5 inches in length.

Table 16.—Coefficient of condition (K) in Lake Decatur white crappie males and females of different length categories. Values of K were not computed where the sexes were not represented by at least 16 specimens. Figures in parentheses represent numbers of specimens.

Date of Collection	Standard Length* and Sex							
	5 Inches		6 Inches		7 Inches		8 Inches	
	Male	Female	Male	Female	Male	Female	Male	Female
1936								
May 29–June 4	—	—	2.69 (16)	2.64 (19)	—	—	—	—
July 31–Aug. 3	2.95 (26)	2.88 (19)	—	—	—	—	—	—
Oct. 24–27	—	—	—	—	3.09 (51)	2.94 (37)	3.29 (53)	3.19 (52)
Dec. 21	—	—	2.90 (18)	3.00 (20)	3.20 (94)	3.12 (72)	3.31 (38)	3.25 (50)
1937								
March 1–4	—	—	—	—	3.04 (66)	3.01 (36)	3.27 (69)	3.25 (86)
April 24	—	—	—	—	3.01 (16)	2.82 (20)	3.16 (18)	3.05 (45)
June 24	—	—	—	—	2.78 (20)	2.60 (17)	2.85 (26)	2.71 (45)
July 10–16	—	—	—	—	2.77 (16)	2.57 (16)	—	—
1939								
Jan. 9	—	—	2.74 (23)	2.75 (22)	3.00 (37)	2.97 (28)	—	—

* Class center; for example, the 6-inch class includes fish of 5.6 through 6.5 inches in length.

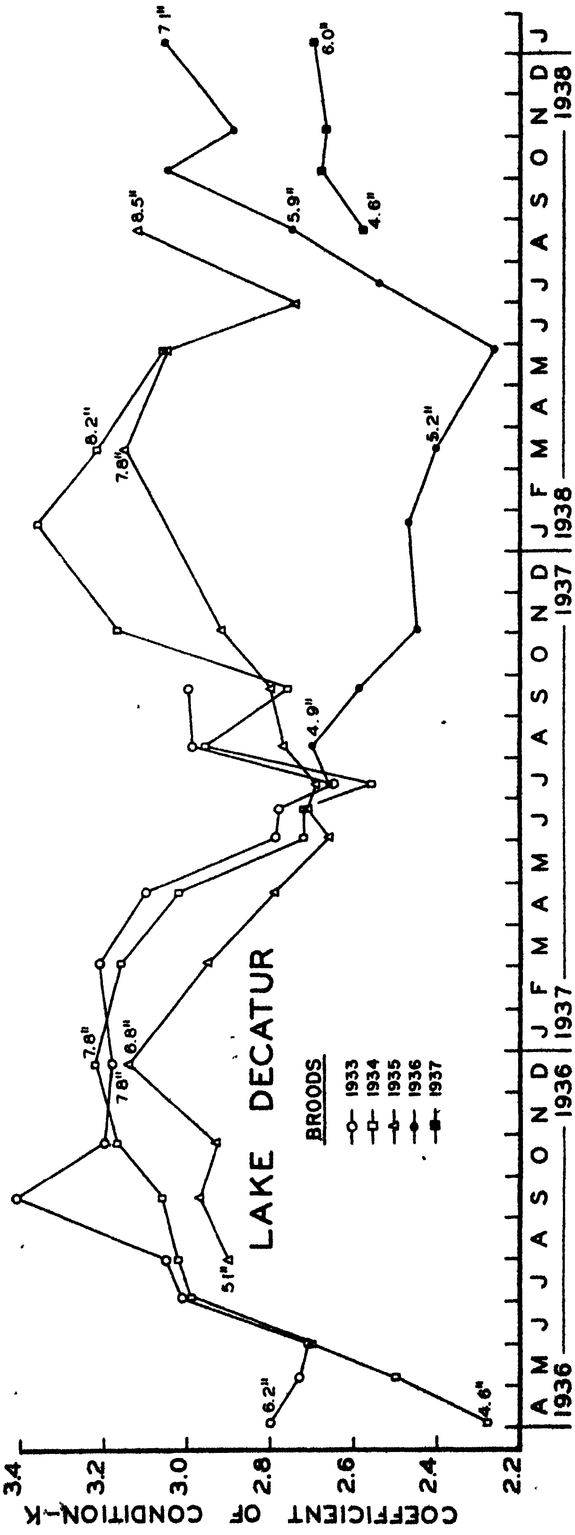


Fig. 8.—Seasonal fluctuations in the coefficient of condition (K) for white crappies belonging to various broods hatched at Lake Decatur, 1933–1937. The major changes in average lengths of individuals of the broods during the period of observations may be seen in the length figures which appear at intervals along the curves. (Data from table 17.)

fluctuations in condition summarized for small fish were similar to those occurring in young fish, and the fluctuations summarized for large fish were similar to those occurring in old fish. Differences in condition between adjoining broods were, as a rule, small, unless members of the adjoining broods differed considerably in length.

Late-summer trends in condition were especially variable from year to year in second-year fish, fig. 8. A late-summer rise in condition was observed in broods making good or moderately good late-summer growth (1935 brood in 1936, and 1937 brood in 1938), but a late-summer loss of condition was observed in a brood whose late-summer growth was small (1936 brood in 1937). The amount of late-summer growth can be seen from the average lengths of fish printed along the curves in fig. 8. With reference to the condition changes in the 1935 brood in late summer of 1936 and the 1937 brood in late summer of 1938, it is apparent that while each brood, taken as a whole, showed a rise in condition, fig. 8, the smaller (4-inch and 5-inch fish, fig. 7) were losing condition.

Eschmeyer, Stroud, & Jones (1944) observed condition changes in white crappies which they refer to as 2-year-olds (apparently the 1940 brood) at Chickamauga Reservoir, Tennessee, from March to October, 1942. This brood of white crappies reached peak condition in June and showed little change in condition from June to October, thus following the trends observed in Lake Decatur crappies of similar age and making the same sort of poor late-summer growth.

Measurements of condition of white crappies in three other Illinois lakes may be seen in table 18. Generally, fish from

Table 17.—Seasonal fluctuations in average coefficient of condition (K) in several broods of Lake Decatur white crappies. Figures in parentheses represent numbers of specimens.

Date of Collection	1933 Brood	1934 Brood	1935 Brood	1936 Brood	1937 Brood
1936					
April 3	2 80 (152)	2 28 (168)	—	—	—
May 4–6	2 73 (18)	2 50 (44)	—	—	—
May 29–June 4	2 71 (59)	2 70 (24)	—	—	—
July 3–5	3 01 (5)	2 99 (36)	—	—	—
July 31–Aug. 3	3 05 (4)	3 02 (27)	2 90 (51)	—	—
Sept. 8–14	3 47 (2)	3 15 (11)	2 99 (14)	—	—
Sept. 22	3 28 (1)	2 97 (11)	2 97 (49)	—	—
Oct. 24–27	3 20 (17)	3 17 (139)	2 93 (69)	—	—
Dec. 21	3 18 (18)	3.22 (107)	3 14 (171)	—	—
1937					
March 1–4	3 21 (53)	3 16 (220)	2 95 (67)	—	—
April 24	3 10 (14)	3 02 (67)	2 79 (35)	—	—
May 16*	3 02 (10)	3 07 (39)	2 93 (37)	—	—
June 3–5	2 79 (32)	2 72 (116)	2 66 (62)	—	—
June 24	2 78 (27)	2 72 (73)	2 71 (27)	—	—
July 10–16	2 65 (15)	2 56 (37)	2 69 (29)	2 66 (6)	—
Aug. 6–14	2 99 (2)	2 96 (8)	2 77 (13)	2 70 (45)	—
Sept. 22	3 00 (2)	2 76 (2)	2.80 (7)	2 59 (206)	—
Nov. 3	—	3 17 (2)	2 92 (3)	2 45 (165)	—
1938					
Jan. 17–24	—	3.36 (3)	—	2 47 (12)	—
March 14	—	3 22 (14)	3.15 (16)	2 40 (181)	—
May 28	—	3 06 (8)	3 05 (4)	2 26 (84)	—
July 1	—	—	2 74 (4)	—	—
July 14	—	—	—	2.54 (24)	—
Aug. 25	—	—	3 12 (2)	2.75 (19)	2.58 (56)
Oct. 6	—	—	—	3 05 (9)	2.68 (59)
Nov. 4–11	—	—	—	2.89 (17)	2 67 (49)
1939					
Jan. 9	—	—	—	3.06 (71)	2.70 (77)

* Sample obtained from anglers.

Table 18.—Average coefficient of condition (K) for various standard length groups of white crappies at Horseshoe Lake, Craborchard Lake, and Senachwine Lake. Figures in parentheses represent numbers of specimens.

Lake	Date	Standard Length, Inches*								
		4	5	6	7	8	9	10	11	12
Horseshoe (Alexander County)	Feb. 19–28, 1938	—	2 75 (31)	2.48 (26)	2.42 (7)	2.76 (4)	3 12 (5)	3 03 (6)	3 32 (10)	3.17 (5)
Craborchard (Williamson County)	March 23, 1944	—	—	—	—	3 70 (3)	3.66 (4)	4.18 (4)	4.03 (2)	—
Senachwine (Putnam County)	Aug. 18–31, 1933	2 85 (16)	2 84 (38)	2 91 (8)	2 99 (3)	—	—	—	—	—
	Sept. 1–16, 1933	2 85 (11)	2 84 (19)	2 93 (11)	2 95 (5)	—	—	—	—	—
	Sept. 21–29, 1933	2 65 (8)	2 82 (44)	2 82 (13)	3 08 (9)	—	—	—	—	—
	Oct. 1–13, 1933	2 82 (4)	2 66 (35)	2 85 (24)	3 10 (14)	3 12 (4)	—	—	—	—

* Class center; for example, the 6-inch class includes fish of 5 6 through 6.5 inches in length.

these lakes show an increase in K with increase in length. An exception may be cited in the Horseshoe Lake data, where the K value of the 5-inch class was considerably higher than the K values for the 6-inch and 7-inch classes.

The condition values of 13 white crappies taken at Craborchard Lake in March, 1944, were much higher than the values observed in crappies of the same size elsewhere in Illinois. In these Craborchard specimens, high condition had accompanied rapid growth. Craborchard Lake was new in 1939. These large Craborchard specimens were observed to be deep bodied in proportion to their lengths and unusually plump in their abdominal regions. The body cavities of dissected specimens contained exceptionally large deposits of fat. No such large deposits were seen in the white crappies of Lake Decatur. In the same Craborchard collections, fish of small sizes appeared to be much less plump than those of large sizes, but they were not weighed and their K values were not determined.

While working for the Natural History Survey at Senachwine Lake on July 31, 1933, Lyle E. Bamber measured and weighed 16 white crappies which ranged from 35 to 49 mm. (1.4 to 2.0 inches) standard length. From their lengths and the absence of annuli on their scales, they were judged to be about 2 months old. They were the only young-of-the-year crappies studied. Their K values varied from 2.01 to 2.46 (average 2.20). Length and weight measurements were made with the degree of accuracy desirable for such small fish, as described in the section "Methods and Techniques."

Collections of 4- to 7-inch white crappies measured at Senachwine Lake during the period August 18 to October 13, 1933, showed changes in condition that approximately corresponded with the autumn changes in condition in 4- to 7-inch crappies at Lake Decatur; the 4-, 5-, and 6-inch classes showed a loss in condition and the 7-inch class a slight rise in condition from August to October, table 18.

Possible Reasons for K Loss

The fact that spring was a time of sharp decline in plumpness of Lake Decatur white crappies suggests a possible connection between weight loss and spawning. The major weight loss in mature white crappies occurred over a 2-month period preceding the nesting season. It appears likely that, in the years we are dealing with, most of the nesting took place within the period May 15 to June 15. Russell (1914) suggested that a prespawning condition loss in the haddock was caused by diversion of food materials to the ripening sex organs. But since two other species, the sardine studied by Clark (1928) and the bluegill studied by Bennett, Thompson, & Parr (1940), showed a rise in condition just before spawning and also since there was a spring loss of condition in immature crappies, it is appropriate to look for other explanations than the one offered by Russell.

Clark (1928), Mottley (1938), and Bennett, Thompson, & Parr (1940) all observed a loss in condition after spawning.

The condition losses in mature white crappies are too large to be accounted for by reduction in weight of the ovaries and testes after spawning. Weighing of the gonads of a few white crappies ranging from 6.5 to 10 inches standard length showed that just before the spawning season the ovary weight amounted to 6 per cent of the total body weight, and the testes weight amounted to less than 1 per cent of the total body weight, while the average winter-to-spring weight loss of the entire fish amounted to about 15 per cent in both sexes.

It was found, as already mentioned, that small white crappies underwent a loss in condition in late summer and fall when they were increasing slowly in length. The possibility can be disregarded that the spring condition loss of larger fish was brought about by growth in length of the crappies without sufficient gain in weight to maintain K values at a constant level. Annulus formation studies showed that only a few of the mature Lake Decatur white crappies had started their 1937 growth by early June, and that the majority delayed their 1937 growth until July or August. Thus, at the time of their spring loss in condition, the large crappies were not growing in length.

Other possible reasons for spring condition loss among white crappies include

disease, seasonal scarcity of fattening foods (or food in general), and difficult feeding conditions resulting from high turbidity. Disease as a possible reason for weight loss is suggested by the apparent high summer mortality of Lake Decatur crappies, a mortality indicated by low net catches in summer, table 20. No data are available on seasonal variations in crappie foods at Lake Decatur. It is not known that high turbidity in spring seriously interfered with crappie feeding. On the contrary, crappies caught in the spring of 1937 seemed to be having considerable success in capturing gizzard shad.

The reason for late-summer loss of condition in small crappies remains as obscure as the reason for their condition loss in the spring.

AGE AND GROWTH

The uses to which growth data on fish may be put depends in large measure on the accuracy of age determinations. In many instances, annual rings on the scales of white crappies appear to give only approximations of age, and the practical application of the scale method of age determination in these fish has been limited in Illinois mainly to detection of stunted populations.

Age Determination

Evidence was obtained at Lake Decatur during studies on date of annulus formation in white crappies that the age rings, fig. 9, are not invariably formed at the rate of one ring for each year of life nor at exactly the same time of year. This evidence may be summarized as follows:

1. In 1935 and 1937 some individuals failed to form annual rings because they did not grow in those years. While the observed cases of failure to form these rings appeared to include only a small proportion of the total population, there seemed to be a possibility that the percentage of cases was high in certain broods.
2. In the collection of September, 1937, 65 per cent of the members of the 1936 brood had two annuli, one of which was necessarily false. The false annulus, or the one thought to be false, while comparatively inconspicuous in some individuals, was well defined in others; some annuli showed cutting-over similar to that shown in fig. 9 and in other respects bore a close resemblance to the rings ordinarily considered to be true year marks.
3. In many scales collected at Lake Decatur the first annulus was indistinct and in some scales it was missing. Commonly the first annulus was present on some scales but absent on other scales of the same fish. A similar variation in visibility of supposedly first rings was commonly observed in collections from other Illinois localities.
4. Annulus formation occurred in different individuals at quite different times in the spring or summer from early May to late August, table 23. The over-all period in which different fish in the population were forming annuli lasted from 6 weeks in some years to 10 weeks or longer in other years.

White crappies collected during the period of annulus formation cannot be aged accurately by scale reading unless, under rather unusual circumstances as at Lake Decatur, the fish can be assigned to broods on the basis of scale patterns, fig. 10. No method has yet been discovered for determining in all cases whether marginal growth represents growth of the current season or of the previous season. While absorption at the edge of the white crappie scale (in summer collections) apparently indicates that the new year's growth has been delayed (Hansen 1937), the lack of absorption may not mean that growth of the current year has already started. Absorption seems to be of irregular and unpredictable occurrence. Summer, then, is not the most favorable time for collecting scales for age studies.

From the Lake Decatur collections it appears, in spite of many exceptions, that formation of one ring for each year of life is at least usual in white crappies. But the fact that many departures from a strictly annual rate were found, and the additional fact that the scale reader would not ordinarily be in position to detect those departures, tends to limit the confidence which can properly be placed in any single reading. Adding greatly to the difficulty of scale reading is the imprecise manner in which many of the rings are formed. Age determination in the white crappie is not

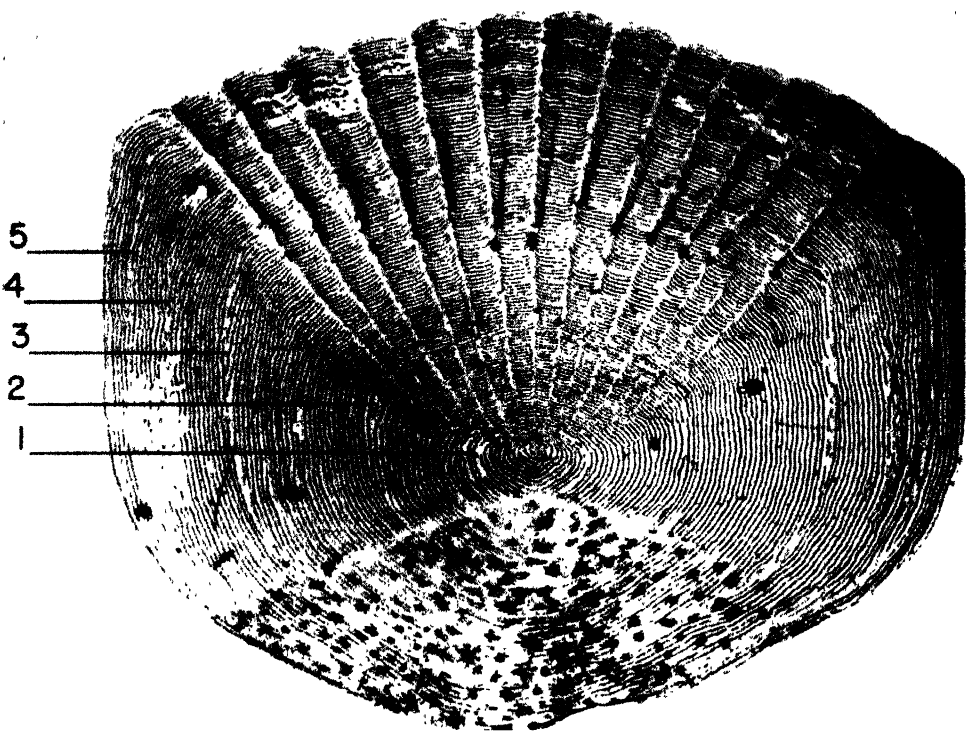


Fig. 9.—Scale from a white crappie that measured 10.1 inches when captured from the Rock River at Lyndon, Illinois, March 14, 1931. Cutting-over is unusually conspicuous in one of the lateral fields of annulus 3. The annulus or annual ring (five annuli are shown in the scale pictured) is a mark separating successive zones of annual growth. It makes its appearance on the scale when the fish begins a new season of growth rather than at the termination of a season of growth. The successive dark lines between the annuli represent ridges termed circuli. The distances between adjacent annuli are approximately proportional to growth increments of the fish in the years represented. The fish from which this scale was taken was not of known age, but its age is estimated to have been about 5¾ years. Its age was greater than that of most crappies taken from Illinois waters. Relatively few crappies live longer than 3 or 4 years.

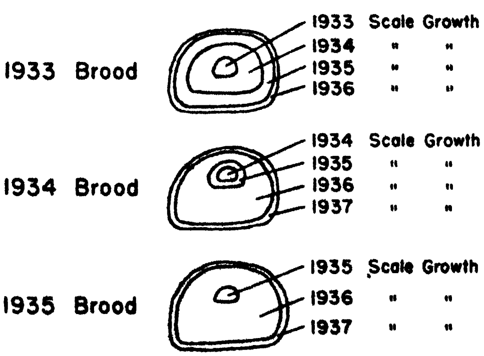


Fig. 10.—Annual ring patterns, that is, ring spacing, of white crappie broods hatched at Lake Decatur in the years 1933, 1934, and 1935. These ring patterns served to make individuals of the broods recognizable in later years.

a simple process of counting clearly defined marks of uniform appearance but instead is one which usually involves picking the true marks from an assortment which, to the scale reader, may seem to include some true rings, some false rings, and some rings which might be either one or the other.

Because of these several possible sources of error in aging white crappies through scale reading, the handling of the scale reading for the present paper needs explanation. Reading was carried on from the point of view that the scale method of aging fish should be used even though in many instances the age read might be only an approximation of the true age. However, it is believed that in only relatively

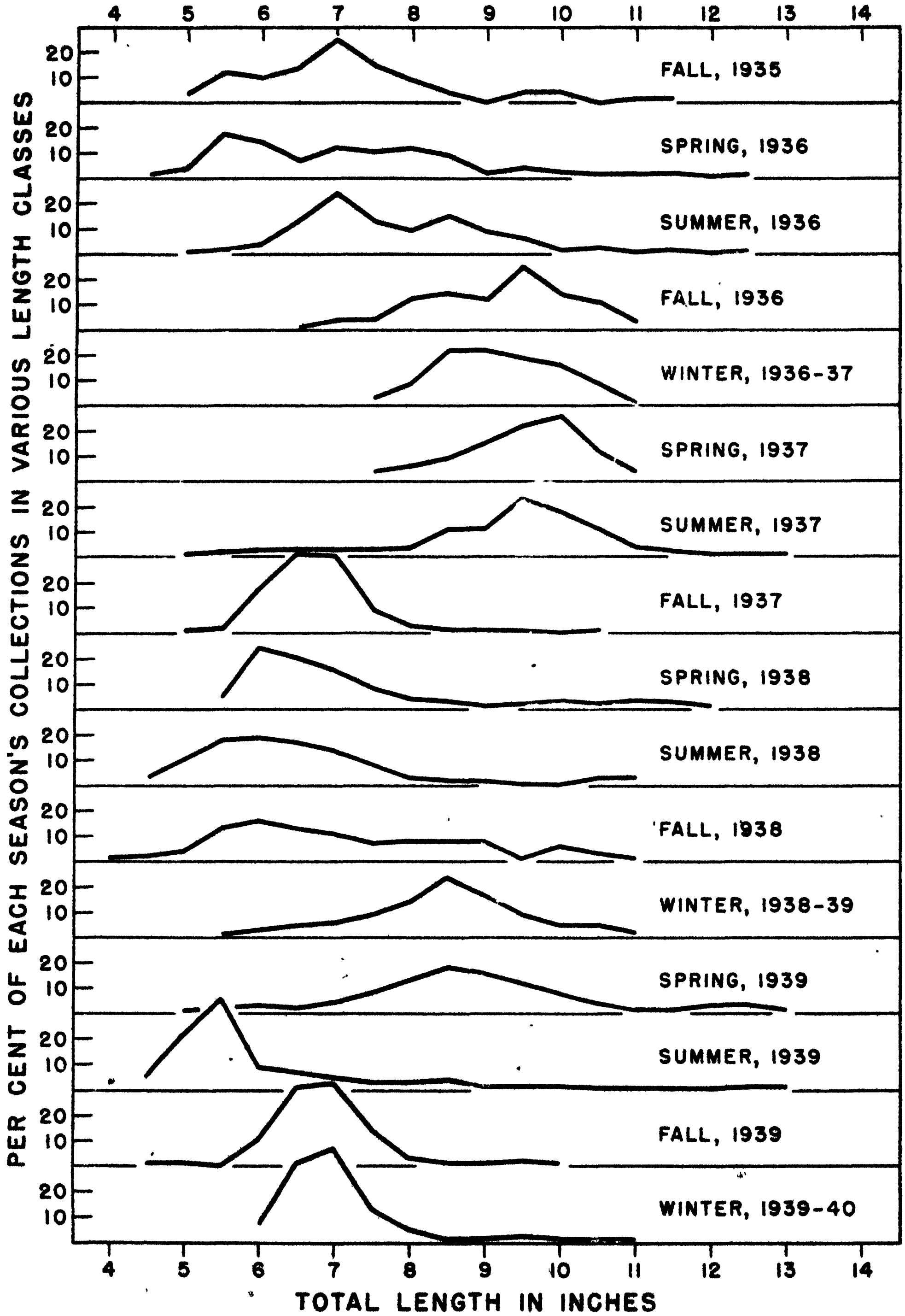


Fig. 11.—Length-frequency distribution (by half-inch classes) of Lake Decatur white crappies collected during the period 1935–1940. (Data from table 19. Some seasons omitted from graph because of meager data.)

few cases of age approximation did the age read deviate from the true age by more than a year.

Few scales were discarded for lack of their easy readability. If, on an individual scale, a ring was present that was believed to be false, the ring was omitted from the count. Conversely, a ring was sometimes counted, though imperfectly shown, or even entirely lacking, if supplementary information, such as length of fish, indicated that it should have been present. However, no addition was made to the count in the case of an unformed ring of the current year in a fish collected within the period of annulus formation.

The lack of a thoroughgoing study of age reading in crappies of positively known ages means that it is not yet possible to judge the success with which ages usually have been puzzled out or to appraise the effect of errors introduced either by faulty ring formation or faulty scale reading.

The Lake Decatur white crappie scales studied intensively for several years were usually more easily understood and probably read with a greater degree of accuracy than the scales from other places in the state. Favoring accurate determinations in the Lake Decatur scales were wide fluctuations in annual growth, which produced ring spacing patterns that were generally diagnostic for the various broods. Fig. 10 shows these patterns in three broods. Two later broods were separated on a length basis.

Size and Age Distribution

The size distribution in net catches of white crappies at Lake Decatur changed considerably from year to year, table 19 and fig. 11. Catches in some years included many large crappies; in other years mostly small. Moderate to large sizes, 8 to 11 inches, were prevalent in the nets at two periods (in alternate years) during the 4 years of study: from the fall of 1936 to the summer of 1937 and from the fall of 1938 to the spring of 1939. Occasional

Table 19.—Length distribution of white crappies caught in hoop nets at Lake Decatur; collections are grouped according to 3-month periods—spring: March, April, May; summer: June, July, August; fall: September, October, November; and winter: December, January, February. The same data expressed as percentages are plotted in fig. 11.

Total Length, Inches*	Fall, 1935	Spring, 1936	Summer, 1936	Fall, 1936	Winter, 1936–37	Spring, 1937	Summer, 1937	Fall, 1937	Winter, 1937–38	Spring, 1938	Summer, 1938	Fall, 1938	Winter, 1938–39	Spring, 1939	Summer, 1939	Fall, 1939	Winter, 1939–40
4	—	—	—	—	—	—	—	—	—	1	—	1	—	—	1	—	—
4½	—	3	—	2	—	—	—	—	1	1	3	3	—	1	33	3	1
5	2	17	1	1	—	—	6	2	—	1	12	5	—	6	135	2	1
5½	9	78	4	—	—	—	9	9	—	22	21	19	2	12	225	1	3
6	8	65	7	1	—	1	18	70	1	79	22	23	4	15	54	27	58
6½	11	29	25	2	—	2	17	125	7	67	20	18	8	13	43	83	260
7	18	53	47	12	1	2	16	121	4	51	16	15	9	21	33	90	298
7½	12	41	26	14	8	17	16	35	—	25	9	10	14	44	20	39	102
8	7	52	18	40	22	28	24	10	—	14	3	12	21	77	21	7	40
8½	3	40	30	45	66	40	58	3	—	8	2	11	37	106	24	3	11
9	—	10	17	39	66	70	57	4	—	3	2	11	26	93	7	3	11
9½	3	19	12	80	57	101	122	4	1	7	—	1	14	67	5	4	17
10	3	9	2	44	148	117	95	1	—	11	—	8	7	45	4	2	7
10½	—	4	4	36	22	55	59	3	—	7	3	4	8	25	1	1	4
11	1	3	—	9	4	17	21	—	2	9	3	2	3	7	1	—	4
11½	1	3	2	1	—	2	9	1	—	8	—	—	—	7	2	—	—
12	—	—	—	—	—	—	4	—	2	4	—	—	—	15	—	—	—
12½	—	2	2	—	—	1	4	—	—	—	—	—	—	16	6	1	—
13	—	—	—	—	—	1	4	—	—	—	—	—	—	7	4	—	—
13½	—	—	—	—	—	—	2	—	—	1	—	—	—	2	—	—	—
14	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—
Total	*78*	*428*	*197*	*326*	*294*	*454*	*541*	*388*	*18*	*320*	*116*	*143*	*153*	*579*	*619*	*266*	*817*

* Class center; for example, the 6-inch class includes fish of 5.8 through 6.2 inches in length.

observations of fishermen's stringers showed that nets were good indicators of the sizes likely to be caught by anglers.

Changes in Size Distribution.—Three separate factors enter into the changes in size distribution in the net samples: (1) availability in summer of broods hatched in the previous year; (2) summer growth of individual fish; and (3) periodic large-scale, and somewhat sudden, natural mortality of large fish, leaving for a time mainly fish of small sizes. The removal of large crappies by anglers is believed to have been a minor factor contributing to the periodic scarcity of large fish in the net samples.

Conspicuous changes in size distribution in white crappie populations were observed by Thompson & Bennett (1938) in an Illinois lake and by Wickliff *et al.* (1944, 1946) in several Ohio lakes. Size distribution changes in a black crappie population were observed by Thompson (1941). Thompson suggested that a single successful brood of black crappies hatched at Senachwine Lake in 1 year was able to consume most of the young crappies hatched for 3 or 4 years thereafter. When this first brood reached an age of 4 or 5 years, its members were sufficiently reduced by mortality that another brood survived in abundance. There is no evi-

Table 20.—Number of white crappies of various broods taken in hoop-net catches and number caught per net-day at Lake Decatur.

Date of Collection[1]	Hoop-Net Days[2]	1933 Brood		1934 Brood		1935 Brood		1936 Brood		1937 Brood	
		Number	Number per Net-Day	Number	Number per Net-Day	Number	Number per Net-Day	Number	Number per Net-Day	Number	Number per Net-Day
1936											
April 3	16	152	9.7	168	10.5	—	—	—	—	—	—
May 4–6	4	18	4.5	44	11.0	—	—	—	—	—	—
May 29–June 4	7	59	8.3	24	3.4	—	—	—	—	—	—
July 3–5	6	5	8.3	36	6.0	—	—	—	—	—	—
July 31–Aug. 3	5	4	8.0	27	5.4	51	10.5	—	—	—	—
Sept. 8–14	6	2	0.3	11	1.8	14	2.3	—	—	—	—
Sept. 22	4	1	0.2	11	2.7	49	12.2	—	—	—	—
Oct. 24–27	12	17	1.4	139	11.6	69	5.7	—	—	—	—
Dec. 21	15	18	1.2	107	7.1	171	11.4	—	—	—	—
1937											
March 1–4	16	53	3.3	220	13.7	67	4.2	—	—	—	—
April 24	6	14	2.3	67	11.2	35	5.8	—	—	—	—
June 3–5	12	32	2.7	116	9.7	62	5.2	—	—	—	—
June 24	9	27	3.0	73	8.1	27	3.0	—	—	—	—
July 10–16	27	15	0.6	37	1.4	29	1.1	6	0.2	—	—
Aug. 6–14	30	2	0.1	8	0.3	13	0.4	45	1.5	—	—
Sept. 22	6	2	0.3	2	0.3	7	1.2	206	34.3	—	—
Nov. 3	6	0	—	2	0.3	3	0.5	165	27.5	—	—
1938											
Jan. 17–24	17	0	—	3	0.2	0	0.0	12	0.7	—	—
March 14	9	0	—	14	1.0	16	1.8	181	20.1	—	—
May 28	8	0	—	8	1.0	4	0.5	84	10.5	—	—
July 1–14	9	0	—	0	—	4	0.4	24	2.7		
Aug. 25	14	0	—	0	—	2	0.1	19	1.4	56	4.0
Oct. 6	10	0	—	0	—	0	—	9	0.9	59	5.9
Nov. 4–11	20	0	—	0	—	0	—	17	0.9	49	2.5
1939											
Jan. 9	12	0	—	0	—	0	—	71	5.9	77	6.4

[1] June 22, 1936, data omitted because of uncertainties in age determination.
[2] The number of hoop net days was obtained by multiplying the number of nets by the number of (24-hour) days they were fished.

dence that one brood dominated later broods in this manner at Lake Decatur, where strong broods were produced each year.

Changes in Age Distribution.—The entry of young broods into the net samples and the dropping out of older ones at Lake Decatur is shown somewhat roughly in table 20 by changes in the rate of catch in nets. The relatively short life span of broods was an outstanding characteristic of the Lake Decatur white crappie population. Assuming that June 1 was the approximate hatching date for all broods, it may be determined from table 20 that the 1933 brood disappeared from the net samples at an age of about 4 years and 4 months, the 1934 brood at 4 years, and the 1935 brood at 3 years and 3 months. But each of these broods showed a major decline in numbers a full year preceding its final disappearance from the samples, table 20. Longer life spans were observed in some broods in Lake Decatur, table 24, and in a number of other localities, table 28. It may be noticed, however, that fish with more than three annual rings were frequently scarce in Illinois collections. The highest number of annual rings, observed among several thousand age readings, was eight, table 28.

Influence of Periodic High Mortality on Size and Age Distribution.—The sharp drop in summer netting rates, table 20, suggests that heavy mortality occurred at Lake Decatur in one or more broods during the summer months in 1936, 1937, and 1938. Most broods, however, showed a certain amount of recovery in rate of nettability from summer to winter, indicating that the depressed summer rates were, in part, the result of low efficiency of summer netting operations. There is no clear indication of high summer mortality in these broods during their second summer of life—the first summer of net capture.

Lack of age readings prevented inclusion of most of the 1939 catch figures in table 20. However, there is evidence of considerable summer mortality among large crappies in 1939 from the fact that fish of the larger sizes were relatively more abundant in the spring than in the other seasons of that year, table 19 and fig. 11.

Normal variations in net catches make it impossible to give the exact date of highest summer mortality. It is suspected that highest losses may have occurred in June or July when the older crappies were at the lowest point in the annual condition cycle, although inquiries among lake-shore residents failed to show that dead crappies were more abundant along shore in June or July than at other times of the year.

Annual Growth Period

The beginning of the annual growth period of white crappies is marked by formation of the annual ring or annulus, fig. 9. Data on the time of annulus formation in white crappies at Lake Decatur in 1935 and 1936 have been published (Hansen 1937). Data for 1937 and 1938 are given in tables 21 and 22. A summary of data for the 4 years is given in table 23. The method of determining the time of annulus formation in crappies of 1937 and 1938 collections was more precise than the method used with the 1935 and 1936 collections. Because of the distinctive ring patterns of most broods of Lake Decatur white crappies in 1937 and 1938 collections, fig. 10, individual fish were assigned to their respective broods. Scales were then examined for presence or absence of annuli of the current growing season and for marginal growth beyond the new annuli.

On the basis of these studies, it is apparent that some white crappies of Lake Decatur started their annual growth much earlier than others, as much as 6 weeks earlier in one season to 10 weeks earlier in another. Generally, small, sexually immature fish formed their annuli earlier than large, mature ones.

The end of the annual growth period is estimated from the data on average length of fish in the various age classes in successive summer, fall, and early winter collections, table 24. Judged by length observations in well-represented age classes—classes with one or two annual rings—the fish of most Lake Decatur broods stopped growing about the latter part of September. However, there is indication that members of some broods may have continued to grow, but at a very slow

rate, during the months of October and November.

For two reasons it is not possible to state with certainty when growth stopped completely. First, there were gaps of a month or more between collections. Second, the length averages calculated for some broods tended to be erratic; for in-

Table 21.—Data on annulus formation in white crappies at Lake Decatur in 1937.

Date of Collection	1935 Brood			1934 Brood			1933 Brood		
	Total Number Caught	Number Having the 1937 Annulus	Per Cent Having the 1937 Annulus	Total Number Caught	Number Having the 1937 Annulus	Per Cent Having the 1937 Annulus	Total Number Caught	Number Having the 1937 Annulus	Per Cent Having the 1937 Annulus
March 1–4	67	0	0 0	220	0	0 0	54	0	0 0
April 24	34	0	0 0	67	0	0.0	14	0	0 0
May 16	37	0	0 0	39	0	0 0	10	0	0 0
June 3–5	71	8	11.5	117	0	0 0	36	0	0 0
June 24	27	3	11 1	74	1	1 3	26	0	0 0
July 10–16	30	12	40.0	37	1	2 7	15	0	0 0
Aug. 6–14	15	15	100 0	9	8	89.0	1	1	100 0
Sept. 22	5	5*	100 0	2	2*	100 0	—	—	—
Nov. 3	2	2*	100 0	2	2	100 0	—	—	—

* One of these fish showed an incomplete stage of annulus formation where new circuli were present on some of the scales but not others, or where new circuli were present only in certain areas of some scales.

Table 22.—Data on annulus formation in white crappies at Lake Decatur in 1938.

Date of Collection	1936 Brood			1935 Brood			1934 Brood		
	Total Number Caught	Number Having the 1938 Annulus	Per Cent Having the 1938 Annulus	Total Number Caught	Number Having the 1938 Annulus	Per Cent Having the 1938 Annulus	Total Number Caught	Number Having the 1938 Annulus	Per Cent Having the 1938 Annulus
March 14	—	—	—	12	0	0 0	13	0	0.0
May 28	69	0	0 0	5	0	0 0	5	0	0 0
July 1	4	2	50.0	2	0	0 0	2	0	0 0
July 14	24	6	25 0	—	—	—	1	0	0 0
Aug. 25	18	18*	100 0	2	1	50 0	1	1	100 0
Oct. 6	—	—	—	2	2	100 0	—	—	—
Nov. 4–11	—	—	—	4	4	100 0	1	1	100.0

* One of these fish had the annulus on only a part of its scales; of those scales which did not have the annulus some showed absorption and some did not.

Table 23.—Approximate periods of annulus formation in white crappies at Lake Decatur, 1935–1938.

Year of Observation	Approximate Dates of Annulus Formation*	Approximate Length of Period
1935	Early May to early July or later	2 months or longer
1936	Early May to early July	1½ to 2 months
1937	Mid-May to early August or later	2½ months or longer
1938	Early June to late August or later	2½ months or longer

* The term "or later" is added when some individuals had still not formed the annulus at the approximate end of the period.

Table 24.—Average observed total lengths, in inches, of Lake Decatur white crappies of various ring classes at time of hoop-net capture in all seasons. Collections made during the period of annulus formation may include members of two different broods in the same annual ring class (fish with a like number of visible rings). Figures in parentheses represent numbers of specimens.

Date of Collection	Number of Fish	Annual Ring Class						
		0[1]	1	2	3	4	5	6
1935								
Nov. 22	78	—	6.5 (47)	7.9 (29)	11.4 (2)	—	—	—
1936								
April 3	324	—	6.0 (165)	7.9 (152)	10.2 (3)	10.4 (2)	9.8 (2)	—
May 4–6	75	—	6.1 (44)	8.1 (27)	11.5 (2)	12.4 (1)	11.7 (1)	—
May 29–June 4	100	—	6.9 (14)	8.1 (76)	10.9 (6)	12.0 (1)	11.7 (3)	—
July 3–5	45	—	6.8 (3)	7.7 (37)	8.1 (5)	—	—	—
July 31–Aug. 3	73	—	6.6 (51)	8.4 (19)	8.8 (3)	—	—	—
Sept. 22	61	—	8.1 (49)	9.3 (11)	9.6 (1)	—	—	—
Oct. 24–27	237	—	8.6 (71)	9.8 (149)	10.1 (17)	—	—	—
Dec. 21	297	4.5 (1)	8.7 (170)	9.9 (107)	9.9 (18)	9.8 (1)	—	—
1937								
March 1–4	346	—	8.6 (67)	9.6 (220)	9.9 (54)	10.7 (2)	12.8 (2)	11.7 (1)
April 24	117	—	8.6 (36)	9.8 (67)	10.1 (14)	—	—	—
May 16	86[2]	—	8.9 (37)	10.0 (39)	10.0 (10)	—	—	—
June 3–5	233	—	8.4 (63)	9.6 (125)	19.3 (37)	11.7 (4)	12.0 (3)	11.5 (1)
June 24	140	—	8.2 (28)	9.6 (76)	10.5 (27)	12.1 (3)	12.7 (5)	11.7 (1)
July 10–16	94	—	7.6 (25)	9.5 (48)	9.8 (16)	12.1 (4)	—	12.1 (1)
Aug. 6–14	74	—	6.4 (47)	8.7 (17)	10.2 (8)	10.4 (2)	—	—
Sept. 22	218	—	6.8 (207)	8.7 (7)	9.0 (2)	10.4 (2)	—	—
Nov. 3	170	—	6.5 (165)	9.2 (3)	10.3 (2)	—	—	—
1938								
Jan. 17–24	18	4.3 (1)	6.6 (12)	—	11.5 (3)	10.8 (2)	—	—
March 14	212	4.3 (2)	6.8 (179)	9.9 (16)	10.3 (14)	—	14.0 (1)	—
May 28	108	—	6.3 (86)	9.4 (5)	11.0 (12)	11.4 (4)	—	13.4 (1)
July 1	8	—	5.8 (2)	9.3 (6)	—	—	—	—
July 14[3]	29	—	5.7 (22)	6.0 (6)	11.1 (1)	—	—	—
Aug. 25	79	—	6.0 (58)	7.6 (19)	10.7 (2)	—	—	—
Oct. 6	67	—	7.5 (57)	8.9 (9)	10.3 (1)	—	—	—
Nov. 4–11	59	3.8 (1)	7.7 (44)	9.5 (10)	10.9 (2)	10.1 (1)	12.2 (1)	—
1939								
Jan. 9	159	4.1 (5)	7.7 (77)	9.0 (71)	10.5 (2)	10.9 (3)	—	13.0 (1)

[1] Only the largest representatives of the 0 group were caught in 1-inch-mesh nets.
[2] Caught by anglers.
[3] About six more large crappies, 10 to 11 inches long, were discarded without being measured or scales being taken.

stance, in 1937 collections, table 24, fish with one scale ring showed greater average length in September than in November.

Taking into account known individual differences in the beginning of the growing period and the uncertainties as to the end of the period, and ignoring any small growth which may have occurred in November, it may be estimated that the longest period of growth of any individual in any year was between 5 and 6 months, May 1 to September 30 or May 1 to October 31. It is almost certain, however, that in some years no individual grew for more than 4 months, that is, from June 1 to September 30. Since small, immature fish began growing earlier in the year than the spawners, the small fish probably grew for a longer period than the large fish.

The period of growth obviously was much less than 4 months for those white crappies that formed their annuli between the middle of July and the latter part of August. In 1937 the majority of individuals began their growth some time between the collecting dates of July 10 and August 14, and in 1938 between July 14 and August 25. The total growth period for these fish could not have been longer than 2 or 3 months. In 1935 and again in 1937 occasional individuals did not grow at all, and it is conceivable that some others may have started to grow as late as September or October and may have grown for less than a month.

Crappies of the 1934 brood seined from a Sangamon River overflow during the high water of 1935 had made little progress on their second year's growth when they were taken in June and early July, table 27.

Jones (1941) observed that largemouth and smallmouth bass in Norris Reservoir, Tennessee, grew for 4 months in 1939. In the same locality in 1940, Eschmeyer & Jones (1941) found that black crappies grew for about 5 months and that largemouth, smallmouth, and Kentucky bass grew for about 5 or 6 months. These writers did not record that individuals began growth at widely different times.

Growth Rates

White crappie growth rates were found to vary in different waters of the state

Table 25.—Average observed total lengths, in inches, of Lake Decatur white crappies of various ring classes at time of hoop-net capture between growing seasons. Data from table 24. Figures in parentheses represent numbers of specimens.

Date of Collection	Annual Ring Class					
	1	2	3	4	5	6
Nov. 22, 1935	6.5 (47)	7.9 (29)	11.4 (2)	—	—	—
April 3, 1936	6.0 (165)	7.9 (152)	10.2 (3)	10.4 (2)	9.8 (2)	—
Average	***6.1*** (212)	***7.9*** (181)	***10.7*** (5)	***10.4*** (2)	***9.8*** (2)	—
Dec. 21, 1936	8.7 (170)	9.9 (107)	9.9 (18)	9.8 (1)	—	—
March 1–4, 1937	8.6 (67)	9.6 (220)	9.9 (54)	10.7 (2)	12.8 (2)	11.7 (1)
April 24, 1937	8.6 (36)	9.8 (67)	10.1 (14)	—	—	—
Average	***8.7*** (273)	***9.7*** (394)	***9.9*** (86)	***10.4*** (3)	***12.8*** (2)	***11.7*** (1)
Nov. 3, 1937	6.5 (165)	9.2 (3)	10.3 (2)	—	—	—
Jan. 17-24, 1938	6.6 (12)	—	11.5 (3)	10.8 (2)	—	—
March 14, 1938	6.8 (179)	9.9 (16)	10.3 (14)	—	14.0 (1)	—
Average	***6.7*** (356)	***9.8*** (19)	***10.5*** (19)	***10.8*** (2)	***14.0*** (1)	—
Nov. 4–11, 1938	7.7 (44)	9.5 (10)	10.9 (2)	10.1 (1)	12.2 (1)	—
Jan. 9, 1939	7.7 (77)	9.0 (71)	10.5 (2)	10.9 (3)	—	13.0 (1)
Average	***7.7*** (121)	***9.1*** (81)	***10.7*** (4)	***10.7*** (4)	***12.2*** (1)	***13.0*** (1)
Grand average	*7.3*	*9.1*	*10.5*	*10.6*	*12.2*	*12.3*

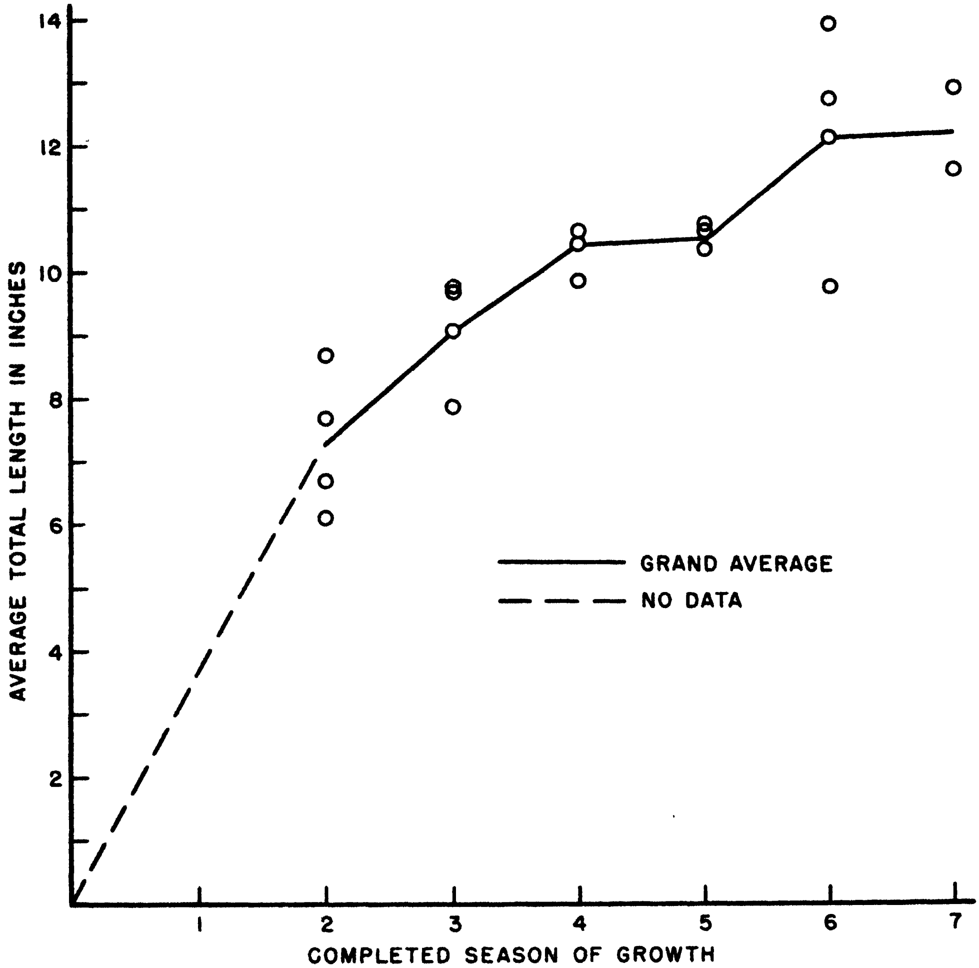


Fig. 12.—Observed average total lengths of Lake Decatur white crappies at end of various completed growing seasons. Each circle shows the average length of individuals of the same age found in winter collections of different calendar years. Sizes of crappies at end of first growing season are not shown, as fish were then too small to be taken in nets.

and from year to year in the same water—notably in Lake Decatur.

Growth Rates at Lake Decatur.—At the time of this study the average growth rate of the white crappies of Lake Decatur, as shown at the bottom of table 25, was probably equal to, if not faster than, the average rate for this species in other waters of the state, table 28.

The tendency toward rapid growth of the Lake Decatur white crappies means that, even though fish of large sizes were periodically almost wiped out by high mortality, rapid growth of the surviving younger fish resulted in a new supply of large fish within about a year of the time when scarcity of large fish set in.

Growth of fish in the second and third years of life varied from good to poor, but poor growth was not seen in any one brood for 2 years in succession, and in all broods fish reached an average length of about 8 inches or more within their first three growing seasons.

Average sizes of Lake Decatur white crappies of six annual ring classes are shown in table 25 and fig. 12. Fish were placed in a given annual ring class in accordance with the scale reading practices described in the section "Age Determina-

Table 26.—Average observed total lengths, in inches, of Lake Decatur white crappie males and females. Figures in parentheses represent numbers of specimens.

Date of Collection	Annual Ring Class 1		2		3		4		5		6	
	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females
1936												
July 31–Aug. 3.	6.6 (27)	6.5 (24)	8.4 (14)	8.4 (13)	8.8 (2)	9.2 (2)	—	—	—	—	—	—
Sept. 8–22.	8.1 (37)	7.7 (25)	9.2 (14)	9.4 (9)	9.6 (1)	9.5 (2)	—	—	—	—	—	—
Oct. 24–27.	8.6 (42)	8.6 (25)	9.9 (70)	9.8 (74)	9.2 (7)	10.8 (10)	—	—	—	—	—	—
Dec. 21.	8.7 (96)	8.7 (76)	9.8 (51)	9.9 (54)	9.4 (6)	10.0 (12)	—	—	—	—	—	—
1937												
March 1–4.	8.6 (34)	8.4 (18)	9.6 (96)	9.8 (98)	9.8 (19)	10.1 (28)	9.8 (1)	11.3 (1)	—	12.5 (1)	—	11.7 (1)
April 24.	8.8 (15)	8.7 (19)	9.6 (22)	9.8 (45)	10.4 (4)	10.1 (10)	—	—	—	—	—	—
June 3–5.	8.6 (34)	8.6 (25)	9.6 (45)	9.4 (44)	10.1 (10)	10.4 (25)	—	11.7 (4)	—	12.0 (3)	11.5 (1)	—
June 24.	8.8 (16)	8.6 (8)	9.5 (30)	9.8 (45)	10.4 (6)	10.5 (19)	—	12.1 (3)	—	12.9 (5)	—	11.7 (1)
1938												
Nov. 4–11.	7.8 (27)	7.6 (22)	9.8 (5)	9.2 (12)	10.4 (3)	10.8 (1)	10.1 (1)	—	12.2 (1)	9.2 (1)	—	—
1939												
Jan. 9.	7.8 (51)	7.5 (26)	9.3 (33)	8.9 (38)	10.8 (1)	10.3 (1)	10.8 (2)	11.3 (1)	—	—	—	—
Average	*8.3* (379)	*8.2* (268)	*9.6* (380)	*9.6* (432)	*9.9* (59)	*10.3* (110)	*10.4* (4)	*11.7* (9)	*12.2* (1)	*12.0* (10)	*11.5* (1)	*11.7* (2)

Table 27.—Average size of white crappies after approximately one season of growth, based on direct observation of young fish. In the estimation of age it was assumed that the fish were spawned about June 1.

Body of Water	Date of Observation	Number of Specimens	Approximate Age, Months	Average Total Length, Inches
Buck's Pond, Monticello	Oct. 6, 1938.	115	4	2.6
Ortman's Lake, Crescent City	Oct. 19, 1933.	37	4½	3.7
Lincoln Lakes, Lincoln	May 20, 1938	17	12	3.7
Sangamon River overflow below Lake Decatur Dam	May 20–22, 1935	61	12	3.5
	June 26, 1935*	50	13	3.6
	July 11–16, 1935.	96	13½	3.7

* The fish in this collection and the one following were a little more than a year old but making slow second-summer growth.

tion." For example, all fish having scales that the reader interpreted as having one ring were placed in annual ring class 1. The fish of that category represented in this table were believed to have completed two seasons of growth.

The data in table 25 were taken from table 24 and include only fish caught from early November to late April, a time of year when the fish were not growing in length (except perhaps at a very slow rate) and annual rings were not being formed.

Comparisons of the year-to-year growth of the Lake Decatur white crappies of various broods can be made by reading the boldface type in table 25 diagonally downward from left to right. For example, fish of the 1934 brood showed one scale ring and averaged 6.1 inches in the combined collections of November 22, 1935, and April 3, 1936. It is this same brood that showed two rings and averaged 9.7 inches a year later in the combined collections of December 21, 1936, March 1–4, and April 24, 1937.

Comparisons of the average lengths of the fish of different broods at the same attained ages can be made by reading the boldface type in table 25 vertically.

The year 1936 was an exceptionally good growing year at Lake Decatur, particularly for fish in the second and third years of life. The good growth of the 1934 brood in 1936 is shown in the figures cited above. Fish of the 1935 brood averaged 3.5 inches at the start of the 1936 growing season and reached a length of 8.7 inches at the end. (The length at the start of the season was computed from scale measurements; similar computation was not employed elsewhere in this paper.) The exceptionally good growth made by these broods in 1936 is believed to have resulted from heavy feeding on fingerling gizzard shad, *Dorosoma,* which were commonly seen in schools and were regularly found in crappie stomachs during the 1936 growing season. The very good growing season of 1936 came between two very poor growing seasons, 1935 and 1937.

In studies on other centrarchids by Hile (1931), Tester (1932), Hubbs & Cooper (1935), Bennett (1938), Schoffman (1938, 1939), and Bennett, Thompson, & Parr (1940), males and females showed very nearly the same rates of growth, or the males showed a tendency to grow slightly faster than the females. At Lake Decatur, among white crappies that were sexed, table 26, there were only small differences in average lengths of males and females of the same age, and such differences, seldom amounting to more than one-half inch, were not consistently in favor of either sex in the various collections.

Growth Rates in Other Illinois Waters.—Because white crappies are seldom caught in 1-inch-mesh hoop nets until they are 13 to 15 months old, the average size reached by these fish at the end of their first season has been determined by direct observation of young fish captured in four Illinois waters by means other than hoop nets, table 27. The Lincoln Lakes and Buck's Pond samples were taken by poisoning, the Ortman's Lake sample by draining, and the Sangamon River backwater samples by seining.

Table 28.—Average observed total lengths, in inches, of white crappies from various Illinois waters, the fish grouped according to annual ring classes. Figures in parentheses represent numbers of specimens. (Lake Decatur hoop-net collections, 1935–1939, shown in table 24).

Body of Water and Nearest Town	Date	Method of Collection[1]	Number of Specimens	Annual Ring Class							
				1	2	3	4	5	6	7	8
Illinois River and Oxbow Lakes											
Senachwine Lake, Henry	Aug. 18–31, 1933	1 inch H	70	6.3 (54)	7.3 (14)	8.1 (2)	—	—	—	—	—
	Sept. 1–29, 1933	1 inch H	115	6.5 (86)	8.7 (23)	8.9 (6)	—	—	—	—	—
	Oct. 2–13, 1933	1 inch H	80	6.5 (42)	8.3 (38)	—	—	—	—	—	—
	June 8–20, 1934	1 inch H	66	5.2 (15)	7.2 (49)	7.9 (2)	—	—	—	—	—
Clear Lake, Liverpool	Dec. 6–17, 1931	1 inch H & ?	26[2]	7.5 (9)	8.7 (12)	9.0 (4)	9.8 (1)	—	—	—	—
Lake Chautauqua, Havana	Sept. 1–9, 1936	1 inch H	196	6.9 (148)	6.9 (48)	—	—	—	—	—	—
	Nov. 13–14, 1936	1 inch H	78	7.9 (76)	8.2 (2)	—	—	—	—	—	—
River channel, Havana	Jan. 3, 1931	?	23[3]	—	7.8 (10)	8.1 (10)	8.2 (2)	7.5 (1)	—	—	—
	May 11, 1931	¼ inch S	18[3]	6.5 (4)	7.0 (8)	7.1 (6)	—	—	—	—	—
	June 9, 1931	¼ inch S	32[3]	5.3 (13)	6.0 (13)	6.5 (6)	—	—	—	—	—
Matanzas Lake, Havana	Feb. 16–March 4, 1931	1½ inch H	141[3]	6.8 (16)	8.6 (32)	9.3 (85)	9.5 (8)	—	—	—	—
Dierker Lake, Bath	Jan. 24, 1931	1½ inch H	15[3]	—	9.0 (4)	9.5 (10)	9.6 (1)	—	—	—	—
River channel, Bath	Nov. 4–19, 1931	1 inch H	143[3]	8.4 (80)	9.6 (46)	10.0 (15)	10.8 (2)	—	—	—	—
Stewart Lake, Browning	Nov. 5, 1931	1 inch H	15[3]	9.2 (7)	9.8 (7)	11.0 (1)	—	—	—	—	—
Meredosia Bay, Meredosia	June 21–29, 1927	1¼–1½ inch H	15	—	9.3 (9)	10.8 (6)	—	—	—	—	—
	June 23–29, 1931	1 inch H	79	5.7 (10)	6.9 (30)	9.2 (15)	9.3 (19)	9.3 (5)	—	—	—
	July 11–31, 1931	1 inch H	230	6.1 (21)	7.3 (20)	9.0 (44)	9.6 (122)	9.5 (22)	11.3 (1)	—	—
	Aug. 5–7, 1931	1 inch H	50	7.1 (1)	8.3 (8)	8.9 (23)	9.4 (15)	9.5 (3)	—	—	—
	May 18–29, 1934	1 inch H	46	7.8 (19)	9.2 (12)	10.3 (10)	11.3 (2)	11.1 (3)	—	—	—
Mississippi River and Oxbow Lakes											
River channel, Savanna	Sept. 1–7, 1932	1 inch S	27	—	7.6 (8)	7.8 (9)	8.3 (7)	8.7 (2)	8.9 (1)	—	—
River channel, Clinton, Iowa	Sept. 14–20, 1932	1 inch H	33	—	7.8 (22)	8.1 (9)	9.5 (1)	8.9 (1)	—	—	—
River channel, New Boston	Aug. 14–19, 1932	1 inch H & S	39	—	7.9 (9)	7.7 (14)	8.3 (9)	8.7 (5)	9.2 (1)	7.9 (1)	—
Horseshoe Lake, Cairo	March 16–24, 1936	1 inch H	52	7.0 (4)	9.6 (7)	11.3 (36)	14.6 (4)	13.1 (1)	—	—	—
	April 8, 1937	1 inch H	94	7.5 (39)	9.0 (2)	12.1 (10)	13.6 (38)	13.1 (3)	13.3 (1)	13.1 (1)	—
	Feb. 19–27, 1938	1 inch H	178	7.1 (81)	8.7 (71)	12.6 (3)	12.1 (8)	13.9 (15)	—	—	—
	May 7, 1938	1 inch H	47	7.2 (17)	8.2 (20)	8.7 (1)	13.3 (2)	14.1 (5)	14.2 (1)	14.9 (1)	—
	April 19, 1941	2½ inch H	33[2]	—	—	12.9 (2)	12.8 (9)	14.1 (17)	13.1 (1)	15.9 (3)	15.5 (1)
Fox River											
River channel, 1–3 mi. above Grass Lake, Spring Grove	July 10–14, 1930	1½ inch H	17	—	—	8.3 (6)	9.3 (9)	10.3 (2)	—	—	—
River channel, McHenry	July 16–Aug. 1, 1930	1 inch H & S	45	5.1 (3)	7.0 (14)	8.8 (21)	9.8 (6)	8.9 (1)	—	—	—
River channel, above St. Charles dam	Aug. 21, 1930	1 inch H & S	22	5.8 (2)	7.8 (14)	9.8 (3)	10.5 (3)	—	—	—	—
River channel, Wedron	Sept. 5–8, 1930	1 & 1½ inch H	26	—	9.0 (21)	9.0 (4)	8.9 (1)	—	—	—	—

Rock River											
River channel, below Sterling dam	Dec. 22, 1931	1 inch S	41	7.5 (7)	8.7 (22)	9.0 (10)	8.4 (2)	—	—	—	—
Sterling pool, Nelson	Nov. 6, 1934	1 inch H	10	—	8.7 (4)	10.8 (4)	11.5 (2)	—	—	—	—
Sterling pool, Sterling	April 21, 1938	1 inch H	13	7.9 (9)	8.9 (3)	9.5 (1)	—	—	—	—	—
Kaskaskia River											
River channel, Sullivan to Carlyle	Aug. 1–23, 1929	1 inch H	55	6.3 (1)	7.1 (34)	8.1 (16)	7.9 (4)	—	—	—	—
Ohio River and Oxbow Lakes											
River channel, Shawneetown	May 1–21, 1935	1 inch H	197	5.4 (2)	7.0 (84)	7.5 (101)	9.0 (10)	—	—	—	—
Allard Lake, Brookport	March 29–April 4, 1930	1½ inch H	68[3]	—	8.6 (39)	9.3 (23)	9.9 (6)	—	—	—	—
Kinneman Lake, Brookport	April 12–18, 1930	1½ inch H	64	—	8.7 (11)	9.8 (28)	11.9 (13)	11.8 (10)	11.8 (2)	—	—
Lower Saline River and tributaries											
Shawneetown	June 5–12, 1935	1 inch H	18	6.9 (1)	8.2 (6)	9.0 (7)	9.9 (3)	—	11.4 (1)	—	—
Sangamon River											
River channel, Mahomet	June 11–24, 1933	1.6 inch S	33	6.3 (15)	6.8 (15)	6.9 (3)	—	—	—	—	—
	July 7–24, 1933	1.6 inch S	66	6.3 (18)	6.4 (34)	7.0 (14)	—	—	—	—	—
	Aug. 2–18, 1933	1.6 inch S	35	6.0 (16)	6.1 (18)	7.3 (1)	—	—	—	—	—
	Sept. 7–21, 1933	1.6 inch S	48	6.0 (16)	6.5 (31)	7.6 (1)	—	—	—	—	—
River channel, Monticello	July 12–13, 1929	1 inch H	19	—	6.6 (13)	6.0 (5)	8.6 (1)	—	—	—	—
River channel, Decatur	May 17, 1935	A	33	7.9 (23)	7.7 (7)	9.4 (3)	—	—	—	—	—
	June 25–26, 1935	A	108	6.4 (49)	6.9 (51)	7.0 (4)	9.3 (2)	8.1 (2)	—	—	—
	July 11–16, 1935	A	192	6.8 (77)	7.0 (104)	9.4 (9)	8.4 (2)	—	—	—	—
Miscellaneous Lakes											
Maple Lake, Willow Springs	Aug. 10–31, 1937	1 inch H	84	6.6 (7)	7.8 (64)	8.7 (11)	8.8 (2)	—	—	—	—
Lake Bloomington, Bloomington	Sept. 10, 1937	1 inch H	49	6.4 (17)	7.1 (15)	7.5 (17)	—	—	—	—	—
Lincoln Lakes, Lincoln	June 15, 1937	A	34	5.5 (1)	6.9 (5)	6.5 (27)	9.5 (1)	—	—	—	—
	May 20, 1938	P	146	5.6 (45)	6.3 (58)	6.6 (3)	7.0 (40)	—	—	—	—
Weldon Springs Lake, Weldon	July 7, 1936	1 inch S	28	—	7.2 (4)	7.6 (20)	8.4 (4)	—	—	—	—
	Sept. 6, 1938	P	115	5.4 (49)	6.1 (64)	6.1 (1)	—	—	12.8 (1)	—	—
Homewood Lake, Decatur	April 12, 1938	1 inch H	88	6.3 (33)	7.1 (28)	7.2 (23)	7.3 (3)	6.8 (1)	—	—	—
	June 16–29, 1938	1 inch H	87	5.7 (8)	6.4 (52)	7.1 (21)	6.9 (6)	—	—	—	—
	July 21, 1938	P	47	—	6.4 (36)	6.9 (9)	7.3 (2)	—	—	—	—
Mattoon Lake, Mattoon	March 12–14, 1931	1 inch S	18[4]	6.5 (3)	8.4 (5)	8.7 (6)	9.6 (2)	12.8 (1)	15.4 (1)	—	—
Pollywogs, Danville	Feb. 28, 1931	1 inch H	12[3]	—	9.9 (7)	9.6 (2)	8.9 (1)	9.9 (1)	11.0 (1)	—	—
	Dec. 26, 1931–April 9, 1932	1 inch H	30[3]	9.5 (1)	9.4 (27)	10.3 (2)	—	—	—	—	—

[1] Method of collection: A—Angling, H—hoop net, S—seine, P—introduced poison (rotenone), H & S—hoop net and seine, H & ?—hoop net and unspecified devices, ?—unspecified devices. Mesh sizes refer to bar or square measure in inches. The mesh size of a hoop net is given only for the pot of the net.
[2] Extent of selectivity not known.
[3] Not a random sample. In most of these selective samples, scales were not taken from individuals under about 6 inches total length.
[4] Probably not a random sample, but all sizes represented to some extent

Table 29.—Selected examples of rapid growth and slow growth in Illinois white crappies. Observed total lengths in inches. (Data from tables 24 and 28.) Figures in parentheses represent numbers of specimens.

Body of Water and Nearest Town	Date of Collection	Annual Ring Class						
		1	2	3	4	5	6	7
(Populations Exhibiting Rapid Growth)								
Horseshoe Lake, Cairo	April 8, 1937	7 5 (39)	9.0 (2)	12 1 (10)	13 6 (38)	13 1 (3)	13.3 (1)	13.1 (1)
Lake Decatur, Decatur	March 14, 1938	6 8 (179)	9 9 (16)	10 3 (14)	—	14 0 (1)	—	—
Kinneman Lake, Brookport	April 12–18, 1930	—	8 7 (11)	9 8 (28)	11 9 (13)	11 8 (10)	11.8 (2)	—
Meredosia Bay, Meredosia	May 18–29, 1934	7 8 (19)	9.2 (12)	10 3 (10)	11 3 (2)	11 1 (3)	—	—
Illinois River channel, Bath	Nov. 4–19, 1931	8 4 (80)	9 6 (46)	10 0 (15)	10 8 (2)	—	—	—
(Populations Exhibiting Slow Growth)								
Weldon Springs Lake, Weldon	Sept. 6, 1938	5 4 (49)	6 1 (64)	6 1 (1)	—	—	12 8 (1)	—
Lincoln Lakes, Lincoln	May 20, 1938	5 6 (45)	6 3 (58)	6 6 (3)	7 0 (40)	—	—	—
Homewood Lake, Decatur	April 12, 1938	6 3 (33)	7 1 (28)	7 2 (23)	7 3 (3)	6 8 (1)	—	—
Ohio River, Shawneetown	May 1–21, 1935	5 4 (2)	7 0 (84)	7 5 (101)	9.0 (10)	—	—	—
Sangamon River, Mahomet	Sept. 7–21, 1933	6 0 (16)	6 5 (31)	7 6 (1)	—	—	—	—
Kaskaskia River, Sullivan to Carlyle	Aug. 1–23, 1929	6 3 (1)	7 1 (34)	8 1 (16)	7 9 (4)	—	—	—

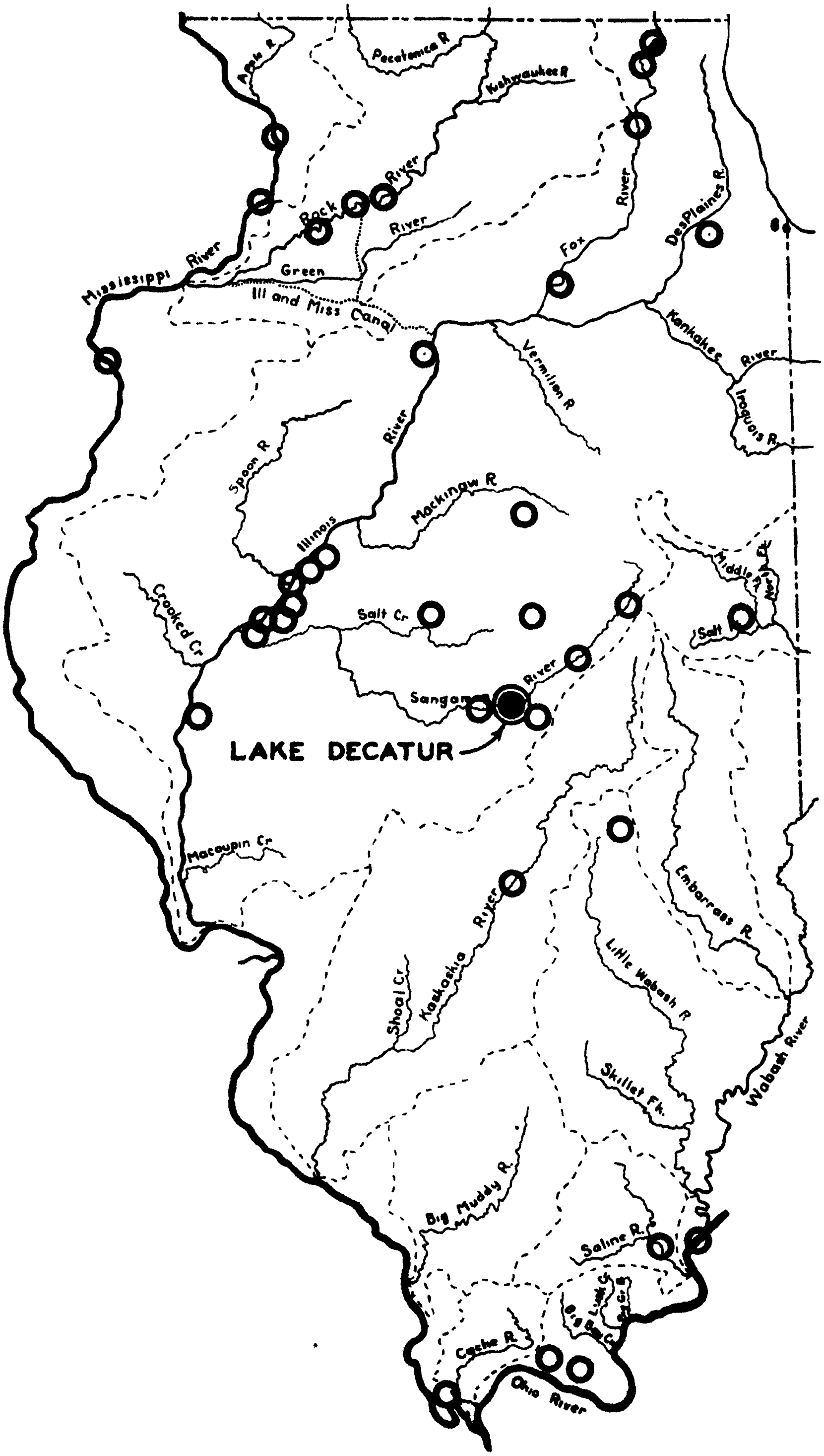


Fig. 13.—Illinois localities represented by age determinations of fish included in table 28.

In Illinois waters other than Lake Decatur, study of growth in fish more than a year old was based on scale samples from lakes or streams in 33 localities in widely scattered sections of the state, fig. 13. Lengths of fish having a like number of annual rings were averaged for each collecting period at each locality, table 28.

Table 28 shows wide differences in sizes of fish having a like number of annual rings. Some of these averages are not subject to direct comparison, since small fish in the samples were not always adequately represented. Especially was this true in several samples collected in 1931 and before (footnote 3, table 28). Some collections were made during the active growing period of the fish collected, while others were made between growing periods. In the case of summer collections, it was not known whether the outer ring on a scale was the ring of the current year or of the preceding year.

Data on some of the outstanding examples of white crappie populations containing fast-growing and slow-growing fish are recorded in table 29. Populations containing slow-growing fish like those found in Weldon Springs, Lincoln, and Homewood lakes are termed "stunted." Such populations contain only a small percentage of crappies over 8 inches in length even though a large percentage are 3 to 5 years old. Growth in these populations is not so abnormally slow during the first 2 years as during the third year and later.

Of all Illinois waters sampled, Horseshoe Lake, in Alexander County, contained the largest white crappies. In this lake, annual growth increments were especially large among fish that had lived beyond the third year. Also, the rate of survival of fish beyond the fourth year appears to have been exceptionally high. The Horseshoe Lake population has been analyzed previously by Thompson & Bennett (1938). Probably the good growth observed in this lake was due to the recent origin of the population. The lake was drained in 1930 and refilled and restocked in 1931.

Lake Decatur, where growth was rapid, and Homewood, where growth was slow, table 29, are in the same central Illinois locality; Homewood Lake was formed by damming one of the small valleys tributary to Lake Decatur.

Growth Rates in Out-of-State Waters.—Growth of the white crappie has been studied in three neighboring states: at Reelfoot Lake, Tennessee, by Schoffman (1940); at Lake of the Ozarks, Missouri, by Weyer (1940); in Indiana lakes by Ricker & Lagler (1942) and Johnson (1945); and in three TVA reservoirs, two in Tennessee and one in North Carolina, by Stroud (1949). The growth rates observed in these bodies of water fall approximately in the range observed in Illinois waters.

Eschmeyer & Jones (1941) found that, in the early years of impoundment of Norris Reservoir, the black crappies there grew at a much faster rate than has yet been observed in Illinois white crappies. The first brood of black crappies hatched in Norris Reservoir (in 1937) averaged 11.5 inches (total length) when they had completed two summers of growth. (The best recorded growth for an adequate sample of Illinois white crappies with two completed summers was found at Lake Decatur in the winter collections of 1936–37. The fish of these collections averaged 8.6 inches in length.) The third brood of black crappies hatched at Norris Reservoir (in 1939) grew at about the same rate in their first summer as Illinois white crappies of the same age, but the rate of growth in their second year, when they reached 8.9 inches, was faster than the best average for Lake Decatur.

Eschmeyer & Jones (1941) attributed the good growth in the early years at Norris Reservoir to abnormal richness of the lake in basic food elements and lack of severe competition.

SUMMARY

This paper is based primarily on an intensive study of the white crappie in Lake Decatur, Macon County, Illinois, where sampling was carried on at 1- to 2-month intervals the year round from late 1935 to late 1939. It is based in part on additional information obtained from various fisheries investigations carried on by members of the aquatic biology staff of the Natural History Survey during an 18-year period beginning in 1927.

The white crappie and the black crappie, both important as sport fishes in Illinois, are abundant throughout the state. The white crappie generally outnumbers the black in small streams or creeks and in artificial lakes of all sizes. The black tends to be the more common species in the deep glacial lakes of northeastern Illinois. In the larger rivers and in the bottomland lakes preponderance of one species over the other varies from lake to lake and from one part of the channel to another.

At the time of this study, fishermen used various methods of angling, some uncommon, and various kinds of baits in fishing for white crappies in Illinois. At Lake Decatur they caught white crappies principally from March 1 to June 1.

In year-round hoop-net fishing at Lake Decatur, the poorest catches were made in the summer.

White crappies require 2 years or, sometimes, 3 years to reach sexual maturity. The smallest ripe female observed in Illinois measured 5.6 inches total length. Dark breeding coloration was found in most males of breeding size from April to June (or July) and was seen in one female. Ripe females (with mature eggs) were found in Illinois as early as May 6 and as late as July 13; ripe males as early as May 16 and as late as June 24. The height of the Illinois spawning season is probably late May or early June. It appears that only a portion of the eggs in ripe females are laid and that perhaps a considerable number of unlaid eggs are absorbed.

Crappies spawn under a variety of conditions of bottom, water depth, and proximity to vegetation, embankments, and wooden structures. They seem to show a preference for depositing their eggs on plant material, but they do not require aquatic plants for that purpose.

Net samples showed a predominance of males among young white crappies, a predominance of females among older white crappies. They showed a temporary scarcity of males in late spring and early summer.

Lymphocystis, the most common disease observed in white crappies, was found in 19.5 per cent of the white crappies in one locality.

Comparisons in the relative plumpness of the members of different length classes and broods were based on the coefficient of condition, K. Small fish usually began their annual growth before large fish and showed earlier summer gains in condition. Large fish reached peak condition in late fall or early winter; small fish reached peak condition in midsummer. Small fish showed condition losses in late summer and additional losses in early spring. Large fish suffered condition losses mainly in spring and early summer.

At most times of the year the K values were higher in large white crappies than in small ones. Differences in K values were least apparent in June and July when the large fish were at the low point in the condition cycle and the small fish were nearing the top of the cycle. K values were approximately the same in males and females of the same size categories, irrespective of time of year.

Evidence obtained at Lake Decatur indicates that the annual rings on the scales of white crappies are not invariably formed at the rate of one ring for each year of life and that the rings are not formed at exactly the same time of year.

The sizes of white crappies caught in the nets at Lake Decatur fluctuated strongly from year to year. Large sizes were abundant only in alternate years. Disappearance of large sizes is believed to have been due to large-scale summer mortality (heavier some summers than others).

Lake Decatur crappie broods were generally short lived. Broods were usually not conspicuous in net catches beyond the second or third year of life. One brood disappeared completely at the age of 3 years and 3 months; another brood at 4 years and 4 months.

Dates of annulus formation were obtained for 4 consecutive years at Lake Decatur. Start of growth ranged from early May in some fish to late August or later in others.

The annual growth period at Lake Decatur varied for most individual fish from about 2 to 6 months. Some individuals failed to grow at all in 1935 and 1937.

The average observed lengths of white crappies falling into various annual ring classes were recorded for Lake Decatur

and 33 other Illinois localities. The annual growth increments of the white crappies at Lake Decatur varied widely from year to year. This was true particularly of fish in the second and third years of life, which grew exceptionally well in 1936 but made little or no growth in 1935 and 1937.

Only small differences in the growth rates of males and females were found among the white crappies of Lake Decatur.

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Commercial and Sport Fishes of the Mississippi River

Between Caruthersville, Missouri, and Dubuque, Iowa

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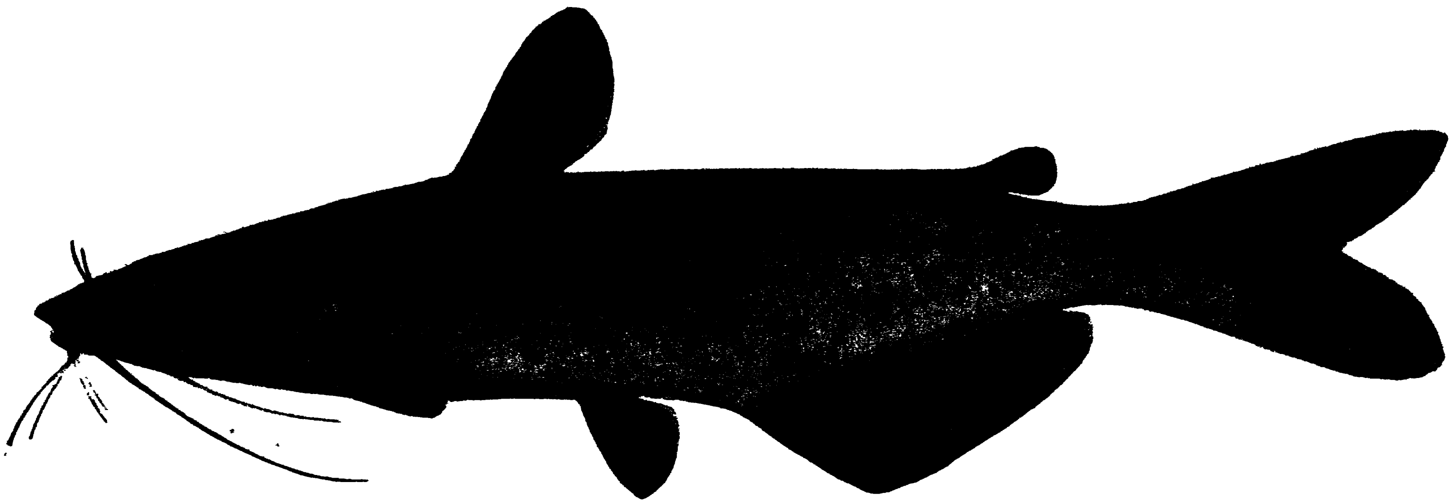
CONTENTS



Channel catfish, one of the species important to the commercial catch of the Mississippi River.

Commercial and Sport Fishes of the Mississippi River

*Between Caruthersville, Missouri, and Dubuque, Iowa**

PAUL G. BARNICKOL†
WILLIAM C. STARRETT‡

IN December, 1943, conservation representatives from the states of Illinois, Iowa, Missouri, Minnesota, and Wisconsin, from the United States Fish and Wildlife Service, and from other interested agencies met at Dubuque, Iowa, and formed the Upper Mississippi River Conservation Committee (Smith 1949). This group was organized for the purpose of sponsoring studies of the fishery and wildlife resources of the Mississippi River from Caruthersville, Missouri, to Hastings, Minnesota. The studies were designed to serve as a basis for making scientifically sound recommendations for the management of these resources. At that time the fish and game codes of the member states were at variance with one another in certain provisions, and some practices that were legal in the waters of the Mississippi bordering one state were illegal in the waters within the jurisdiction of another immediately across the river.

To facilitate the actual projection of biological investigations, two technical committees were formed within the Conservation Committee. These were the Technical Committee for Fisheries and the Technical Game Committee. To them were assigned the duties of planning research and reporting the progress of research to the Conservation Committee at its annual meetings.

Basic to a sound management program for the upper Mississippi fishery was a knowledge of the status of various species of fish present in the river. Commercial fishery statistics were not adequate because they included several species under single groupings, as buffalofishes and catfishes, and because in recent years they failed to include sport fishes and other species closed to commercial fishing.

Because state agencies were restricted in their research activities by state boundaries (the United States Fish and Wildlife Service was the only agency involved that was free to finance projects without regard to state boundaries), it became necessary to subdivide the upper Mississippi River fishery investigations into upper and lower co-operative units—the upper unit involving Wisconsin, Minnesota, and northern Iowa, and the lower unit involving Missouri, southern Iowa, and Illinois.

Actual field operations were begun in the Missouri-Illinois part of the southern unit in March, 1944, with the Conservation Commission of Missouri, the Illinois Department of Conservation, and the Illinois Natural History Survey participating. Two years later, in March, 1946, field operations were begun in the Iowa-Illinois part of the river with the Iowa Conservation Commission and the two Illinois agencies co-operating.

The entire investigation reported here was conducted under the auspices of the Technical Committee for Fisheries.

This paper is based on an analysis of the data relative to the species composition

* This investigation was conducted under the auspices of the Technical Committee for Fisheries of the Upper Mississippi River Conservation Committee.

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of the fishes appearing in test-net collections taken in 1944 and 1946 with various types of commercial gear at 31 sampling stations between Caruthersville, Missouri, and Dubuque, Iowa. The gear included types that could not be used legally by commercial fishermen in some or all of the co-operating states.

The discussion is limited largely to the commercial and sport fishes of the river. The smaller-sized fishes, such as the minnows (Cyprinidae), seldom occurred in the test-net collections, as the minimum mesh used was 1 inch square. Minnow collections were made at many of the stations, and a list of the species appearing in these collections was recorded but is not presented here.

The writers believe that, regardless of any shortcomings of the sampling methods employed in this study, the data are extensive enough to allow a rough estimate of the status of the various commercial and game fishes now occurring in the Caruthersville-Dubuque section of the Mississippi.

Acknowledgment is made to the following persons for their various contributions to the progress of the researches reported in this paper: Mr. W. E. Albert, Mr. Daniel Avery, Mr. James S. Ayars, Dr. Reeve M. Bailey, Dr. George W. Bennett, Mr. Leonard Durham, Dr. T. H. Frison (now deceased), Dr. B. Vincent Hall, Dr. Donald F. Hansen, Dr. G. B. Herndon and associates, Mr. Don W. Kelley, Mr. Jacob H. Lemm, Dr. Harlow B. Mills, Mr. Sam A. Parr, Dr. Hurst H. Shoemaker, Mr. Everett B. Speaker and associates, and Dr. David H. Thompson.

Financial support of this investigation was given by the conservation departments of the states of Illinois, Iowa, and Missouri, and by the Illinois Natural History Survey, all co-operating under the Upper Mississippi River Conservation Committee program.

THE MISSISSIPPI RIVER

The length of the Mississippi River from its source at Lake Itasca to its mouth at Head of Passes is 2,470 miles (Mississippi River Commission 1940:1). This great river and its tributaries drain a total area of about 1,244,000 square miles, including all or parts of 31 states and 2 Canadian provinces: New York and Pennsylvania farthest east, Wyoming and Montana farthest west, Alberta and Saskatchewan farthest north. The investigation reported here covers that part of the Mississippi River between Caruthers-

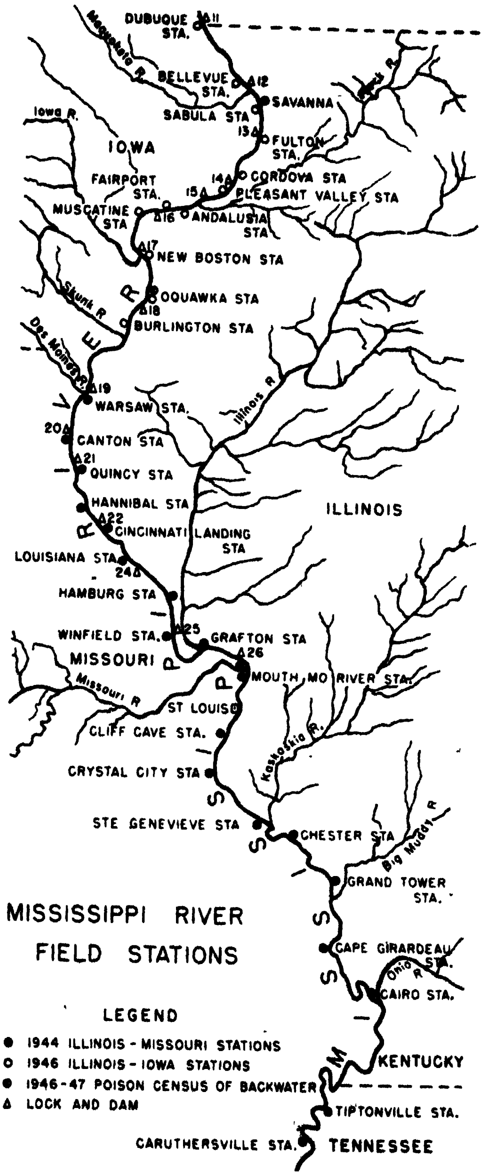

Fig. 1.—The Mississippi River between Caruthersville, Missouri, and Dubuque, Iowa; shown is the location of field sampling stations used during the fisheries survey of 1944 and 1946. The river distance between Caruthersville and Dubuque is 689 miles.

ville, Missouri, and Dubuque, Iowa, a distance of 689 miles or 28 per cent of the total length of the river, fig. 1. This section of the river includes 306 miles of the lower Mississippi, designated hereafter as MR-C (mouth of the Missouri River to Caruthersville), and 383 miles of the upper Mississippi, designated as D-MR (Dubuque to the mouth of the Missouri River).

Early Descriptions

The Mississippi River was discovered in the sixteenth century by an expedition headed by Hernando de Soto. Later explorations were made on the Mississippi by such well-known historical personages as D'Iberville, Joliet, Marquette, and La Salle.

The "Gentleman of Elvas," a Portuguese member of the De Soto expedition, stated that "The river was of great depth and of a strong current. The water was always muddy. There came down the river continually many trees and timber, which the force of the water and stream brought down. There was a great store of fish in it of sundry sorts, and most of it differing from the fresh water fish of Spain" (Saxon 1927:78).

Thomas Jefferson (1801:11) wrote the following description of the river in about 1780: "The Missisipi, below the mouth of the Missouri, is always muddy and abounding with sand bars, which frequently change their places. However, it carries 15 feet water to the mouth of the Ohio, to which place it is from one and a half to two miles wide, and thence to Kaskaskia from one mile to a mile and a quarter wide. Its current is so rapid, that it never can be stemmed by the force of the wind alone, acting on sails. Any vessel, however, navigated with oars, may come up at any time, and receive much aid from the wind."

Reclus (1859:262) in his paper on the Mississippi mentioned the yellow water of the Missouri River and the blue water of the Mississippi at the confluence of the two rivers.

Prior to the construction of locks and dams, two rapids were present in the river between Dubuque and the mouth of the Missouri River. The upper were between Le Claire, Iowa, and Rock Island, Illinois, and the lower at Keokuk, Iowa.

Glazier (1891:314) in describing his trip down the Mississippi in 1881 stated that "We found the current of the Mississippi below the mouth of the Missouri much stronger than we had observed it to be since passing the Keokuk Rapids."

Floods and Levees

Floods along the Mississippi have been reported since the river's discovery. A member of the De Soto expedition in 1543 wrote the first description known of a Mississippi flood. The flood began about the tenth of March and reached its peak about 40 days later. "The inundated areas are said to have extended for twenty leagues on each side of the river" (Mississippi River Commission 1940:8).

Jefferson (1801:11–2) wrote the following regarding floods on the Mississippi: "These floods begin in April, and the river returns into its banks early in August. The inundation extends further on the western than eastern side, covering the lands in some places for 50 miles from its banks. Above the mouth of the Missouri, it becomes much such a river as the Ohio, like it clear, and gentle in its current, not quite so wide, the period of its floods nearly the same, but not rising to so great a height."

The delta with its fertile land early attracted many settlers. This alluvial valley extends up the river as far as Cape Girardeau, Missouri. "In the Alluvial Valley the Mississippi River is an aggrading, or soil-building stream. In time of flood the river goes out of its banks, dropping its load of sediment as it goes. This action is due to the slowing up of the waters as they leave the river's channel; and the larger share of this material settles on or near the edges of the stream. For this reason the banks are generally from 10 to 15 feet above the lowlands away from the river. The slope away from the river is usually steepest for the first mile away from the river banks" (Mississippi River Commission 1940:9).

For more than two centuries man has used levees in defense of his rich soil and cities against the flooding torrents of the Mississippi. By 1727, a levee along the

Table 1.—Stations where fish collections were taken during 1944 and 1946 on the Mississippi River between Caruthersville, Missouri, and Dubuque, Iowa, with inclusive dates, pool numbers, number of net days at each station, and river stages in feet.*

Station	Inclusive Dates	Miles Below Dubuque Station	Pool No.	Number of Net Days	River Stage at Muscatine	River Stage at Cape Girardeau
	1944					
Caruthersville, Mo.	April 6–12	689	—	42.54	7.7	19.2
Tiptonville, Tenn.	April 15–May 10	665	—	111.70	11.3	38.9
Cairo, Ill.	May 18–24	573	—	54.10	14.2	27.1
Cape Girardeau, Mo.	May 26–31	529	—	61.94	16.7	28.8
Grand Tower, Ill.	June 2–9	499	—	73.13	12.3	30.3
Chester, Ill.	June 11–15	468	—	38.99	11.5	26.5
Ste. Genevieve, Mo.	June 18–24	454	—	46.14	15.8	27.5
Crystal City, Mo.	June 25–30	429	—	62.19	17.5	30.4
Cliff Cave, Mo.	July 2–8	412	—	61.36	15.0	29.0
Mouth Missouri R., Mo.	July 10–15	383	—	62.86	10.8	25.8
Grafton, Ill.	March 22–30	358	26	42.64	9.8	24.9
Grafton, Ill.	July 17–25	358	26	74.30	9.4	21.8
Grafton, Ill.	Sept. 22–27	358	26	93.31	5.7	13.5
Winfield, Mo.	July 27–Aug. 2	337	25, 26	85.92	7.9	18.8
Hamburg, Ill.	Aug. 3–9	320	25	96.60	6.9	16.3
Louisiana, Mo.	Aug. 12–17	295	24	66.71	6.6	15.5
Cincinnati Landing, Ill.	Aug. 19–23	281	24	64.90	6.3	15.1
Hannibal, Mo.	Aug. 25–30	267	22	82.97	5.7	16.2
Quincy, Ill.	Sept. 2–6	256	22	105.20	6.2	20.7
Canton, Mo.	Sept. 8–13	236	21	100.82	5.5	15.9
Warsaw, Ill.	Sept. 14–19	218	20	99.99	6.0	13.0
	1946					
Burlington, Iowa	April 10–22	178	19	143.72	10.2	20.6
Oquawka, Ill.	April 24–May 5	159	18	135.80	7.3	16.6
New Boston, Ill.	May 7–18	143	18	155.00	6.4	22.1
Muscatine, Iowa	May 19–30	134	17	160.00	5.9	19.8
Fairport, Iowa	June 2–13	118	16	158.85	6.8	17.4
Andalusia, Ill.	April 1–7	103	16	98.18	15.0	27.8
Andalusia, Ill.	June 18–26	103	16	155.67	11.4	22.8
Andalusia, Ill.	Sept. 15–24	103	16	196.53	6.0	12.7
Pleasant Valley, Iowa	June 28–July 9	87	15	151.68	10.0	21.3
Cordova, Ill.	July 11–22	75	14	150.17	9.9	18.8
Fulton, Ill.	July 24–Aug. 4	57	14	152.39	5.6	13.0
Sabula, Iowa	Aug. 6–17	44	13	160.31	5.3	11.6
Bellevue, Iowa	Aug. 19–30	17	12	188.40	5.0	17.6
Dubuque, Iowa	Sept. 1–12	0	12	192.83	6.1	10.2

* The 1944 river stage data from the United States Department of Commerce (1946); the 1946 river stage data furnished by Ray K. Linsley, Jr., Acting Chief of Division, Climatological and Hydrologic Services, Washington, D. C. Flood stage is 32 feet at Cape Girardeau, Mo.; 15 feet at Muscatine, Iowa.

Mississippi at New Orleans had been completed to a length of 5,400 feet (Mississippi River Commission 1940:10).

In 1850 the Federal Government approved an act which encouraged the reclaiming of the alluvial land along the Mississippi below the mouth of the Ohio River (Saxon 1927:261). In 1879 the Mississippi River Commission was created and placed in charge of flood control on the Mississippi (Saxon 1927:266).

In that part of the Mississippi River covered by the present investigation, levees and drainage districts border much of the stream up as far as Muscatine, Iowa. Below the mouth of the Missouri River the levees are more apparent than along the upper river and they give the observer an impression that the river is hemmed in by them.

High-water conditions prevailed throughout the 1944 investigation of the MR-C section of the river, as shown in table 1. In several instances during this survey, test-netting was done over flooded land formerly planted in corn or cotton.

Improvements for Navigation

The exciting days of steamboating on the Mississippi described by Mark Twain and others are just about gone. Steamboats are being replaced by diesel-powered towboats capable of pushing huge barges loaded with coal, grain, oil, and other commodities. During the period of World War II approximately 1,980 war

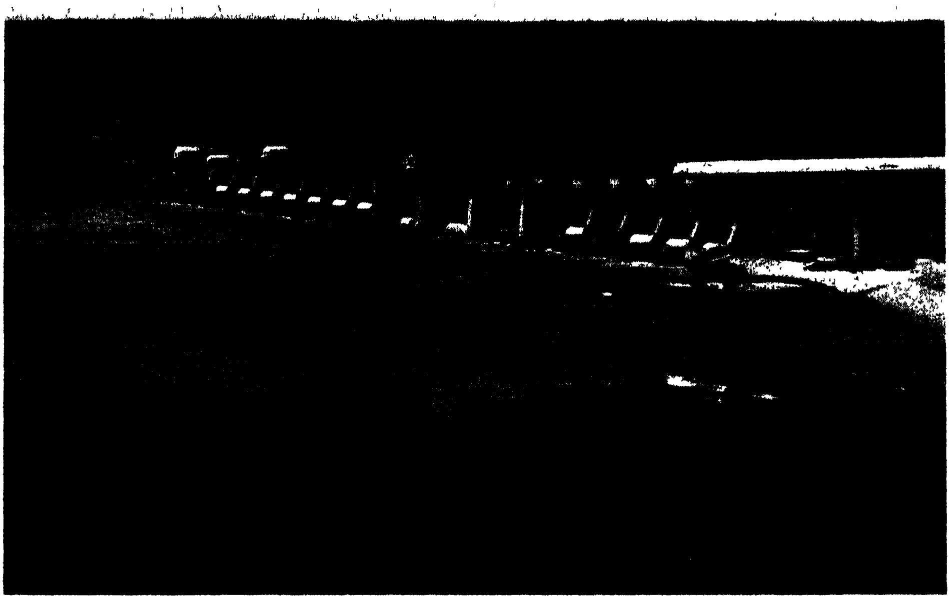

Fig. 2.—Lock and Dam No. 25 just above the Winfield, Missouri, sampling station. The swiftness of the current below the dam is quite perceptible. Photo by courtesy of the United States Army Corps of Engineers, Upper Mississippi Valley Division, St. Louis, Missouri.

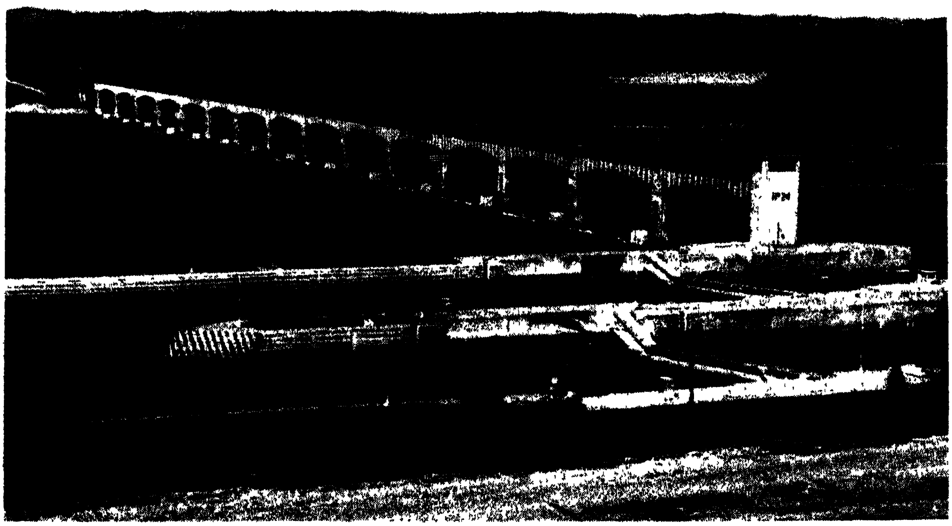

Fig. 3.—Lock and Dam No. 24 just below the Louisiana, Missouri, sampling station on the Mississippi River. Photo by courtesy of the United States Army Corps of Engineers, Upper Mississippi Valley Division, St. Louis, Missouri.

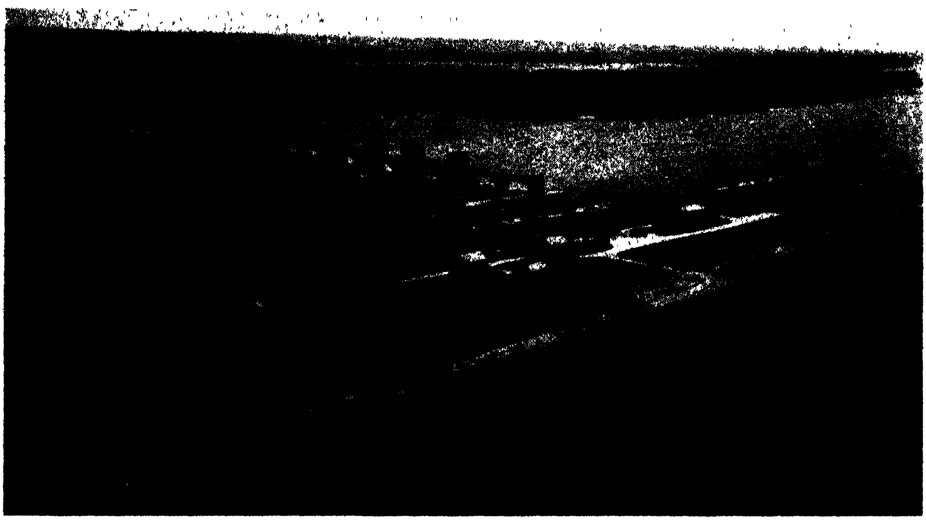

Fig. 4.—Lock and Dam No. 22 just below the Cincinnati Landing, Illinois, sampling station. Photo by courtesy of the United States Army Corps of Engineers, Rock Island District.

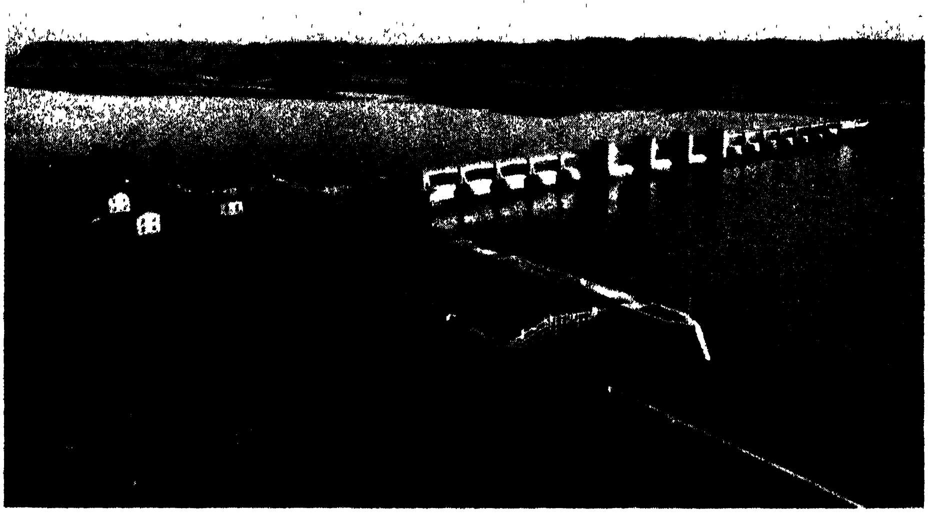

Fig. 5.—Lock and Dam No. 11, and Pool No. 12, from Eagle Point Park, near Dubuque, Iowa. Photo by courtesy of the United States Army Corps of Engineers, Rock Island District.

vessels were passed through the lock at Alton, Illinois (War Department Corps of Engineers 1946:7). These vessels were constructed inland and outfitted for sea at New Orleans, Louisiana.

The use of the river for navigation and the construction of levees for drainage districts and flood control have brought about many changes on the river. As early as 1824 an act was passed by Congress appropriating $75,000 for the improvement of the Mississippi by "snagging" from the mouth of the Missouri River to New Orleans. The first permanent improvement on the river came in the building of a pier at St. Louis, Missouri, to give direction of current. This construction was authorized by acts passed in 1836 and 1837. Later, the Keokuk and Rock Island rapids were improved for naviga-

tion. An act in 1872 authorized improvement of the river between Alton and the mouth of the Meramec River by obtaining channel depths through revetments, solid dikes, and dams. A comprehensive project was approved in 1881 for continuous improvement of the river between the mouth of the Ohio River and St. Louis to secure a minimum depth of 8 feet by using revetments, permeable dikes, and contraction of the low water channels to an approximately uniform width of 2,500 feet. This project was modified by acts passed in 1895 and 1896 providing for the maintenance of a channel 250 feet wide and 9 feet deep by regulating works and dredging. The project was again modified in 1905, providing that the use of regulating works be supplanted by extensive dredging operations. Later, dredging alone proved unsatisfactory; in 1910 regulating works were again approved, and channel depths of 6 feet from the mouth of the Missouri to St. Louis and 8 feet from St. Louis to the mouth of the Ohio were authorized. In 1927 and 1930, acts of Congress authorized a channel depth of 9 feet between St. Louis and the mouth of the Ohio, with a channel width of 300 feet, and a channel depth of 9 feet from the mouth of the Illinois River to St. Louis, with a channel width of 200 feet (War Department Corps of Engineers 1940:5–6). A project for the improvement of the Chain of Rocks Reach in the St. Louis area was approved in 1945. In this 7-mile reach, at low water the stream gradient averaged approximately 1.5 feet per mile in contrast to 0.5 foot above the Chain of Rocks and 0.6 foot from St. Louis to Cairo, Illinois (Smyser 1947:5).

General improvement of the upper Mississippi for navigation between the mouth of the Missouri and St. Paul, Minnesota, was authorized by Congress in 1878. This was to be accomplished by the use of wing dams and closure of chutes to secure a depth of 4.5 feet, eventually to be increased to 6 feet. In the period 1888 to 1906 "the rock cut through Rock Island Rapids was improved to a width of 400 feet and a depth of 6 feet." In 1905 an act was passed to replace the locks and lateral canal at Keokuk with a power dam and navigation locks (War Department Corps of Engineers 1940:6). This project was practically completed in 1913 (Coker 1914:5). An act passed in 1907 provided for a 6-foot channel from Minneapolis, Minnesota, to the mouth of the Missouri River to be accomplished by contraction works, as in the project of 1878, supplemented by dredging and a lateral canal with a navigation lock around the upper portion of the Rock Island rapids at Le Claire (War Department Corps of Engineers 1940:6).

The Board of Engineers for Rivers and Harbors concluded after an investigation that canalization of the Mississippi from the mouth of the Illinois to Minneapolis was the most feasible and economical method of obtaining a dependable 9-foot channel for navigation; plans included the construction of approximately 24 locks and dams (United States 72d Congress, 1st Session, 1932:2, 27). An act of 1930, as modified in 1935, authorized improvement of the Mississippi River from Minneapolis to the mouth of the Missouri River by means of locks and dams supplemented with dredging to provide a channel 9 feet in depth (War Department Corps of Engineers 1940:6). The upper Mississippi from Alton north was canalized by the time the present investigation was started in 1944, figs. 2, 3, 4, and 5. In the Alton-Dubuque section there were 14 locks and dams (Nos. 12–26, excluding 23).

Influence of the Missouri

In the above discussion the descriptions of several early writers were quoted regarding the confluence of the Missouri and Mississippi rivers and the influence of the Missouri on the Mississippi. Prior to agricultural development of the prairies, the upper Mississippi was apparently a relatively clear river, and below the mouth of the Missouri it was always muddy. The D-MR section of the Mississippi was found by the survey party in 1944 and 1946 to be quite muddy; however, it appeared less muddy than the MR-C section. In 1944 Platner (1946:16) found that the turbidity of the Mississippi just above the mouth of the Missouri averaged 300 ppm, whereas, below the mouth of the Missouri it increased to an average reading of 1,880 ppm. At Caruthersville, 306 miles below the mouth of the Missouri,

this high turbidity had diminished only slightly. The turbidity of the Mississippi, according to Platner (1946:12), is caused largely by erosion silt with some detritus. In 1921 Galtsoff (1924:371) found the water in the upper Mississippi muddy even at low water stages and progressively more turbid as he moved downstream.

The current of the Mississippi is swifter below the mouth of the Missouri than above. This difference in current was apparent before canalization, as evidenced by Glazier (1891:314).

According to the War Department Corps of Engineers (1940:3) the velocities in the current of the Mississippi between the mouth of the Wisconsin River and Alton may vary from about 2 miles per hour at usual pool stages to about 4 miles per hour at high water. In the uncanalized or open-river section below Alton, the velocities range from 2.0 to 5.5 miles per hour, except through the Chain of Rocks near St. Louis. In this region velocities as high as 8 miles per hour may occur at both extreme high- and extreme low-water stages. In the pools formed by the locks and dams in the Alton-Dubuque section, the swiftest current appears in the upper parts of the pools.

The bottom of the river proper in the MR-C section is largely sand with occasional silt or mud. The flooded areas in which netting operations were conducted had chiefly mud bottom. The bottom of the canalized D-MR section of the Mississippi varies with location in the pools. In the upper parts of the pools where the current is swift, the bottoms are sand and gravel, whereas, in the middle and lower reaches of the pools, the bottoms are largely silt. The silting in the canalized section of the river is a result of reduction in current caused by the dams. Ellis (1931:4–5) made oxygen determinations of the Mississippi River in the Keokuk area prior to the canalization of the river above the dam at Keokuk (Lock and Dam No. 19). He found that the water before reaching the Lake Keokuk basin was carrying over 20 per cent more oxygen than after it was impounded in the basin. Some 30 miles below Dam No. 19, at La Grange, Missouri, the oxygen content of the water was 10 to 15 per cent less than above the impoundment.

Platner (1946:26) found that the river has a distinct seasonal oxygen pulse. In midwinter, when the river was frozen over with 4 to 8 inches of ice, the dissolved oxygen ranged from 12.40 ppm to 14.95 ppm. During times of low water, in August and September, it ranged from 3.00 to 7.10 ppm. In periods of high water it ranged from 4.30 to 11.50 ppm.

The flooded bottomlands in the canalized D-MR section of the river are less encroached upon by drainage districts, and they seem to provide more suitable backwater and sloughs for spawning, than the bottomlands in the extensive levee and drainage districts of the MR-C section.

On the silt bottom of Lake Keokuk (Pool No. 19), Ellis (1931:8–9) found a few fresh-water mussels near shore; otherwise, on this bottom he found little besides sludge worms, bloodworms, *Corethra* (*Chaoborus*), a few snails of the pulmonate group, tiny bivalves of the genus *Musculium*, and several species of leeches. In the area free of silt, such as on cinders, stones, and water-logged portions of trees, he found large numbers of caddisfly and Neuroptera larvae, flatworms, beetle larvae, and occasionally a few specimens of crayfish, gomphids (dragonfly nymphs), and leeches.

Pollution

Erosion silt is a constant form of pollution in the Caruthersville-Dubuque section of the Mississippi River. Although this form of pollution has long been associated with that part of the Mississippi below the mouth of the Missouri, it was not generally noted in the upper part of the river until after the development of intensive farming in the Middle West.

That silting tends to limit the reproduction of aquatic life has been demonstrated previously. Silting was pointed out as having a detrimental effect on trout and salmon eggs (Smith 1940:229) and on aquatic insects and other invertebrates (Ellis 1931, 1936). In the Des Moines River, high water combined with the river's increased silt load in a period of flood was shown to be an important limiting factor in the spawning success of minnows and other kinds of fishes (Starrett 1951:23).

The impounding of the upper Mississippi with a series of dams created favorable conditions for silting in that section of the river. This impounding was done largely during the thirties, and the present investigation was made perhaps too soon following this period to demonstrate the possible maximum effects that siltation may have on the upper Mississippi fishery.

Platner (1946:71–2) found pollution on the Mississippi limited largely to local areas below cities and industrialized sections. "Even though the volume of water is large enough and the dilution is great enough to render these pollutants harmless to the present fish fauna of the Mississippi River, one must remember that each small amount of material narrows the safety margin of the river." Platner concluded from his chemical studies that the river was not in a critical condition. He further concluded that in the upper section of the river, that is, north of the 420-mile mark above the mouth of the Ohio River (about 4 miles above Oquawka, Illinois), a more "favorable position" existed than in the lower section below mile 420. "Comparing the water quality of the Mississippi River with waters producing good fish fauna, it would be rated as good."

Ellis (1943) conducted a pollution study on the Mississippi River between Chain of Rocks (St. Louis area) and Cairo. He made this study in relation to garbage introduced into the river at St. Louis. In September of 1931 and 1934, during periods of low water, he found that the Mississippi lost a considerable portion of its dissolved oxygen load in the immediate vicinity of St. Louis. Below the city it made a temporary recovery, and between Crystal City, Missouri, and Cape Girardeau it again lost a large amount of its oxygen load. Between Crystal City and Claryville, Missouri, Ellis (1943:8) recorded a maximum of 3.86 ppm of total ammonia. He stated that "This total ammonia of approximately 4 p.p.m. represents a considerable nitrogenous load and shows definitely that the nitrogenous wastes from the St. Louis area are projected downstream 65 or 70 miles before the maximum ammonia production is reached." Below the mouth of the Ohio River, at Wickliffe, Kentucky, the total ammonia content dropped to 1.28 ppm. In 1944 Platner (1946:39) determined that from mile 580 above the mouth of the Ohio to mile 170 above (St. Louis area) the ammonia value ranged from 0.0 to 0.1 ppm and averaged 0.06 ppm. Below St. Louis the ammonia value increased slightly to an average of 0.12 ppm.

During the Caruthersville-Dubuque investigation, notes were taken on obvious pollution conditions existing in this section of the river. The fishery studies in the MR-C section were carried out largely during a period of high water, and in such a period the relative amount of pollutant other than silt is reduced. Commercial fishermen at Ste. Genevieve, Missouri, which is about 55 miles below St. Louis, complained that fishes they catch during the summer low-water stage frequently have an oily or gassy flavor. In the opinion of the fishermen this flavor is attributable to wastes discharged into the river at St. Louis. At Crystal City, also, fishermen registered complaints regarding pollution. In the vicinity of Cliff Cave (12 miles below St. Louis) test nets set in channels became clogged with masses of paper and partially disintegrated ground garbage discharged through the sewers of St. Louis. There, also, commercial fishermen reported that the fish in the area have an oily or gassy flavor; however, fish taken there in early July (Cape Girardeau gage 29.0 feet, table 1) which were served to members of the research party did not appear to have such a flavor. Perhaps this foreign taste is discernible only at low stages of the river when dilution is not sufficient to overcome the effect of the causal agent.

In 1947 commercial fishermen in the vicinity of Valmeyer, Illinois (28 miles below St. Louis), complained that often half of their catches were discarded because of an unpleasant taste resulting from pollution.

Recently Starrett & Harth (1950:8) reported that since 1948 a serious pollution problem has existed on the Mississippi from below Dam 26 to Cairo, and that commercial fishing is now almost nonexistent from the St. Louis area to the mouth of the Kaskaskia River.

Above the mouth of the Missouri River, pollution was observed in the vicinity of

two Illinois stations, Warsaw and Cordova. Warsaw is located about 1.5 miles below the mouth of the Des Moines River. This river receives a rather heavy load of pollution from the city of Keokuk, as was evidenced by the accumulation of sewage and other debris on the test nets. A large portion of this pollution in the Des Moines evidently comes from packing plants. Across the Mississippi River from Keokuk and just below Hamilton, Illinois, the malt wastes from a brewery are discharged into the river. It was obvious from the poor catches of commercial fishes in the test nets that the fish population is adversely affected by the pollution for several miles below Keokuk. According to local reports, commercial fishermen avoid setting their nets within the first few miles downstream from Keokuk on the Iowa side because of the unhealthy appearance of fishes that have been taken at that location. Carp taken in the test nets there appeared to have a rather milky coloration, and many of them showed a form of popeye. It was reported locally that, during the winter season, fishermen operate their nets on the Illinois side of the river near Warsaw to catch carp that apparently feed upon brewery waste and become very fat.

Commercial fishermen at Cordova complained that their hoop nets sometimes became clogged with a slimy substance that was later reported to be a filamentous organism attributed to conditions produced by wastes discharged from plants at Clinton, Iowa, 15 miles upstream. Seines became so loaded with this filamentous growth that they could not be hauled to shore and landed. No ill effect from the filamentous growth or the waste material supposedly responsible for it was observed on the fish at Cordova; in fact, the fish taken there appeared to be more plump than those in the usual catches taken elsewhere on the river. The local fishermen reported no mortality of fish or ill flavor of fish as a result of the waste material.

MATERIALS AND METHODS

In the 2 years of this investigation, collections were taken at 31 different field stations, fig. 1. One station in each year was designated as a key station, Grafton in 1944 and Andalusia in 1946, table 1. Each of the key stations was sampled three times during an 8-month period of field operations as a means of obtaining data on changes in a local fishery.

Usually sampling at a station covered 5 days. However, at some stations more time was spent because of certain unforeseen difficulties, such as those involving bad weather, poor catches, mechanical trouble, or the locating of fishing areas.

Descriptions of the habitats at the field stations are given in Appendix A. Data on the catches made at these stations are presented in tables 2, 3, 4, and 5 and Appendix B, tables 1 and 2.

Netting Operations

The Illinois Natural History Survey's laboratory boat, the *Anax,* was used as field headquarters during this investigation. All fish caught were brought to the laboratory boat. Aboard the boat, technicians measured and weighed each fish, removed scales or vertebrae for growth studies, and recorded the sex and gonad condition of the fish. The haul made with each type of gear, from each station, and in each fishing period was tabulated as an individual catch, and a record was made of specific information on habitat in which gear was fished.

The following types of fishing gear were used during the survey:

25-foot *Common Sense* minnow seine (mesh 1/4 inch)

100-yard trammel nets (mesh 1 1/2, 2, and 3 inches)

100-yard or 200-yard seine (mesh 1 inch)

Hoop nets (mesh 1, 2 1/2, and 3 inches)

Wing nets, with and without leads (mesh 1, 1 1/2, and 2 1/2 inches)

Trap net (mesh 1 1/4 inches)

Basket trap

Trotline

The poundage and numbers of fishes caught by the various types of fishing gear are summarized in tables 2, 3, 4, and 5. Data on the fishes taken in the minnow seine hauls are not included in this paper. Selections of fishing sites were made by two field assistants of the Illinois Natural History Survey, Jacob H. Lemm and Daniel Avery, who had previously been commercial fishermen. Conversation with

Table 2.—Numbers of fish caught with various types of fishing gear in 1944 test-net operations in the Mississippi River at stations from Caruthersville, Missouri, to Warsaw, Illinois, inclusive.

Station	1-Inch Mesh Wing Nets With Leads	1-Inch Mesh Wing Nets Without Leads	1½-Inch Mesh Wing Nets	2½-Inch Mesh Wing Nets	2½-Inch Mesh Hoop Nets	Unclassified Wing Nets and Hoop Nets	Total Wing Nets and Hoop Nets	Trammel Nets	Angling	Basket Traps	Seines	Total Number of Specimens
Caruthersville, Mo..	60	153	—	2	—	243	458	—	—	—	—	458
Tiptonville, Tenn...	89	183	—	4	23	345	644	—	—	—	—	644
Cairo, Ill......	416	196	26	—	7	—	645	—	—	—	—	645
Cape Girardeau, Mo.	—	233	—	57	—	—	290	—	—	4	—	294
Grand Tower, Ill.	262	330	88	38	—	—	718	—	—	23	—	741
Chester, Ill.........	216	85	53	—	—	—	354	—	—	3	—	357
Ste. Genevieve, Mo.	137	191	132	133	—	—	593	—	—	1	—	594
Crystal City, Mo.	157	174	58	69	21	—	479	—	—	—	—	479
Cliff Cave, Mo..	—	200	64	87	14	—	365	—	—	3	—	368
Missouri River (mouth)	190	871	81	67	34	—	1,243	—	1	13	—	1,257
Grafton, Ill. (March)..	1,139	82	—	22	—	—	1,243	—	—	—	—	1,243
Grafton, Ill. (July).	434	381	174	31	5	—	1,025	9	—	—	—	1,034
Grafton, Ill. (Sept.)..	—	493	48	7	6	—	554	—	—	—	—	554
Winfield, Mo..	—	572	56	56	13	—	697	—	—	9	361	1,067
Hamburg, Ill...	89	490	50	49	11	—	689	12	—	4	43	748
Louisiana, Mo. ..	—	247	33	11	2	—	293	—	—	13	31	337
Cincinnati Landing, Ill.	60	140	23	19	4	—	246	—	—	—	—	246
Hannibal, Mo..	29	208	26	17	13	—	293	—	—	—	38	331
Quincy, Ill....	—	506	33	46	11	—	596	103	—	—	283	982
Canton, Mo...	—	363	19	33	57	—	472	—	—	—	70	542
Warsaw, Ill.....	—	326	64	87	59	—	536	3	—	—	53	592
Total........	*3,278*	*6,424*	*1,028*	*835*	*280*	*588*	*12,433*	*127*	*1*	*73*	*879*	*13,513*

Table 3.—Pounds of fish caught with various types of fishing gear in 1944 test-net operations in the Mississippi River at stations from Caruthersville, Missouri, to Warsaw, Illinois, inclusive.

Station	1-Inch Mesh Wing Nets With Leads	1-Inch Mesh Wing Nets Without Leads	1½-Inch Mesh Wing Nets	2½-Inch Mesh Wing Nets	2½-Inch Mesh Hoop Nets	Unclassified Wing Nets and Hoop Nets	Total Wing Nets and Hoop Nets	Trammel Nets	Angling	Basket Traps	Seines	Total Pounds Caught
Caruthersville, Mo.	36.66	156.24	—	2.30	—	122.61	317.81	—	—	—	—	317.81
Tiptonville, Tenn.	72.05	142.71	—	6.05	32.29	270.50	523.60	—	—	—	—	523.60
Cairo, Ill.	522.34	196.14	32.27	—	12.28	—	763.03	—	—	—	—	763.03
Cape Girardeau, Mo.	—	502.20	—	246.92	—	—	749.12	—	—	4.05	—	753.17
Grand Tower, Ill.	344.36	355.43	99.71	118.48	—	—	917.98	—	—	12.69	—	930.67
Chester, Ill.	309.45	157.72	115.97	—	—	—	583.14	—	—	2.16	—	585.30
Ste. Genevieve, Mo.	211.79	341.45	226.83	283.42	—	—	1,063.49	—	—	2.23	—	1,065.72
Crystal City, Mo.	137.35	254.28	121.07	196.49	80.12	—	789.31	—	—	—	—	789.31
Cliff Cave, Mo.	—	367.73	152.51	242.85	37.30	—	800.39	—	—	8.00	—	808.39
Missouri River (mouth)	133.82	574.26	141.22	169.59	97.79	—	1,116.68	—	0.12	11.41	—	1,128.21
Grafton, Ill. (March)	631.51	62.83	—	51.44	—	—	745.78	—	—	—	—	745.78
Grafton, Ill. (July)	222.47	239.46	72.82	71.59	16.28	—	622.62	10.15	—	—	—	632.77
Grafton, Ill. (Sept.)	—	276.41	36.31	13.55	11.29	—	337.56	—	—	—	—	337.56
Winfield, Mo.	—	425.60	46.88	116.49	25.32	—	614.29	—	—	6.88	245.27	866.44
Hamburg, Ill.	35.97	302.29	37.22	74.57	33.08	—	483.13	14.45	—	1.07	35.46	534.11
Louisiana, Mo.	—	216.32	36.24	19.32	2.47	—	274.35	—	—	13.95	46.10	334.40
Cincinnati Landing, Ill.	49.15	211.99	42.53	30.07	14.50	—	348.24	—	—	—	—	348.24
Hannibal, Mo.	28.17	237.60	32.59	42.34	77.82	—	418.52	—	—	—	29.57	448.09
Quincy, Ill.	—	392.42	55.84	125.58	65.44	—	639.28	185.22	—	—	380.51	1,205.01
Canton, Mo.	—	275.46	24.75	57.31	95.82	—	453.34	—	—	—	70.89	524.23
Warsaw, Ill.	—	353.76	74.90	187.47	152.41	—	768.54	6.94	—	—	59.44	834.92
Total	*2,735.09*	*6,042.30*	*1,349.66*	*2,055.83*	*754.21*	*393.11*	*13,330.20*	*216.76*	*0.12*	*62.44*	*867.24*	*14,476.76*

Table 4.—Numbers of fish caught with various types of fishing gear in 1946 test-net operations in the Mississippi River at stations from Burlington, Iowa, to Dubuque, Iowa, inclusive.

Station	1-Inch Mesh Wing Nets	1-Inch Mesh Hoop Nets	2½-Inch Mesh Wing Nets	2½-Inch Mesh Hoop Nets	3-Inch Mesh Hoop Nets	Total Wing Nets and Hoop Nets	1¼-Inch Mesh Traps	Trammel Nets	Seines	Trot-lines	Total Number of Specimens
Burlington, Ia.	873	24	47	50	—	994	—	75	—	—	1,069
Oquawka, Ill.	412	5	43	63	—	523	—	—	—	—	523
New Boston, Ill.	1,095	33	54	52	—	1,234	—	41	50	2	1,327
Muscatine, Ia.	420	6	26	121	—	573	—	262	133	—	968
Fairport, Ia.	351	1	55	30	—	437	—	69	85	—	591
Andalusia, Ill. (April)	286	6	28	5	—	325	—	146	—	—	471
Andalusia, Ill. (June)	561	30	90	124	—	805	—	56	101	—	962
Andalusia. Ill. (Sept.)	387	13	27	24	45	496	69	335	167	—	1,067
Pleasant Valley, Ia.	481	9	33	57	—	580	—	29	—	—	609
Cordova, Ill.	440	35	23	31	—	529	—	72	58	—	659
Fulton, Ill.	1 522	46	41	124	—	1,733	—	79	—	—	1,812
Sabula, Ia.	698	16	15	41	—	770	—	48	—	—	818
Bellevue, Ia.	458	7	15	29	—	509	107	65	—	—	681
Dubuque, Ia.	727	20	29	37	—	813	73	81	—	—	967
Total	*8,711*	*251*	*526*	*788*	*45*	*10,321*	*249*	*1,358*	*594*	*2*	*12,524*

Table 5.—Pounds of fish caught with various types of fishing gear in 1946 test-net operations in the Mississippi River at stations from Burlington, Iowa, to Dubuque, Iowa, inclusive.

Station	1-Inch Mesh Wing Nets	1-Inch Mesh Hoop Nets	2½-Inch Mesh Wing Nets	2½-Inch Mesh Hoop Nets	3-Inch Mesh Hoop Nets	Total Wing Nets and Hoop Nets	1¼-Inch Mesh Traps	Trammel Nets	Seines	Trotlines	Total Pounds Caught
Burlington, Ia.	396.48	12.01	165.91	116.27	—	690.67	—	231.53	—	—	922.20
Oquawka, Ill.	274.36	11.50	124.83	139.16	—	549.85	—	—	—	—	549.85
New Boston, Ill.	625.83	10.47	162.51	159.41	—	958.22	—	116.18	21.62	2.60	1,098.62
Muscatine, Ia.	198.32	2.29	65.76	266.41	—	532.78	—	847.82	41.56	—	1,422.16
Fairport, Ia.	352.81	0.18	124.73	137.11	—	614.83	—	190.85	123.01	—	928.69
Andalusia, Ill. (April)	181.08	2.06	87.24	9.73	—	280.11	—	194.38	—	—	474.49
Andalusia, Ill. (June)	569.54	38.69	240.22	471.36	—	1,319.81	—	81.22	86.90	—	1,487.93
Andalusia, Ill. (Sept.)	192.69	20.28	83.30	72.10	138.18	506.55	112.58	854.66	171.25	—	1,645.04
Pleasant Valley, Ia.	446.76	6.65	112.00	241.24	—	806.65	—	47.22	—	—	853.87
Cordova, Ill.	317.83	16.86	71.63	169.62	—	575.94	—	189.74	10.50	—	776.18
Fulton, Ill.	768.51	58.80	109.42	349.91	—	1,286.64	—	105.70	—	—	1,392.34
Sabula, Ia.	320.10	21.80	43.92	164.06	—	549.88	—	108.24	—	—	658.12
Bellevue, Ia.	255.55	10.29	51.02	126.84	—	443.70	112.14	140.63	—	—	696.47
Dubuque, Ia.	426.96	6.30	116.97	151.67	—	701.90	55.84	153.79	—	—	911.53
Total	*5,326.82*	*218.18*	*1,559.46*	*2,574.89*	*138.18*	*9,817.53*	*280.56*	*3,261.96*	*454.84*	*2.60*	*13,817.49*

Fig. 6.—Commercial fishermen setting a trammel net around a school of carp on the Mississippi River. This type of net was used at several test-net stations.

local commercial fishermen often proved of value in locating a good fishing ground and in selecting effective types of fishing gear. The best available fishing sites were selected, rather than particular types of habitat at each station.

Hoop nets and wing nets usually were lifted after one overnight set. The number of nets used varied with fishing conditions and season.

Trammel-net sets were made at several stations primarily for taking carp and buffalo, fig. 6.

Trammel-net floats were made at stations having smooth bottom and sufficient current to float the nets downstream. These proved to be effective for catching sturgeon.

Basket traps, usually baited with cheese scrapings, were not very satisfactory since it was necessary to take the traps from the water when moving upstream to a new station. The traps are considered by some fishermen to be effective for catfish when left in the water over long periods.

Seines could be used only at stations having sufficient beach to permit efficient landing.

The difficulty of obtaining bait discouraged the use of trotlines.

Two rowboats powered with outboard motors were used in carrying out fishing operations from the *Anax*. When the survey party was traveling between stations these boats were loaded with fishing gear and towed astern of the *Anax*.

Effectiveness of Gear

Each of the various types of gear employed by commercial fishermen is designed for use in a particular type of habitat and for catching a selected kind of fish. The effectiveness and selectivity of gear are mentioned here merely to manifest some of the difficulties encountered in determining the species composition of the fishes in the river, on the basis of catches taken with commercial gear.

The efficiency of hoop nets and wing nets in catching fish decreases during the warm months of the year. The actual poundages and numbers of fish taken at the various stations in the Caruthersville-Dubuque investigation are therefore not indicative necessarily of the abundance of a species at a particular station. Perhaps

Table 6.—Accepted common, scientific, and local names of fishes occurring in Mississippi River test-net or other survey collections between Caruthersville, Missouri, and Dubuque, Iowa, 1944 and 1946.*

Accepted Common Name	Scientific Name	Local Names
Shovelnose sturgeon	*Scaphirhynchus platorynchus* (Rafinesque)	Hackleback, switchtail, sand sturgeon
Paddlefish	*Polyodon spathula* (Walbaum)	Spoonbill cat, spoony
Longnose gar	*Lepisosteus osseus* (Linnaeus)	Garpike, billfish, billy gar
Shortnose gar	*Lepisosteus platostomus* Rafinesque	Duckbill gar
Alligator gar	*Lepisosteus spatula* Lacépède	Mississippi alligator gar
Bowfin	*Amia calva* Linnaeus	Dogfish, grindle, cypress trout, mudfish
Mooneye	*Hiodon tergisus* Le Sueur	Toothed herring, white shad
Goldeye	*Amphiodon alosoides* Rafinesque	Mooneye
Skipjack	*Pomolobus chrysochloris* Rafinesque	Golden shad, river herring, blue herring
Gizzard shad	*Dorosoma cepedianum* (Le Sueur)	Hickory shad
American eel	*Anguilla bostoniensis* (Le Sueur)	Freshwater eel
Blue sucker	*Cycleptus elongatus* (Le Sueur)	Missouri sucker, bluefish, blackhorse, gourdseed sucker
Bigmouth buffalo	*Megastomatobus cyprinella* (Valenciennes)	Redmouth buffalo, stubnose buffalo, roundhead buffalo, brown buffalo, goarhead, bullhead buffalo, bullmouth buffalo, bullnose buffalo, slough buffalo, trumpet buffalo
Black buffalo	*Ictiobus niger* (Rafinesque)	Mongrel buffalo, bugler, rooter, reefer, round buffalo, sheepshead buffalo, blue buffalo
Smallmouth buffalo	*Ictiobus bubalus* (Rafinesque)	Razorback buffalo, roachback buffalo, humpback buffalo, channel buffalo, liner buffalo, quillback buffalo
Quillback	*Carpiodes cyprinus* (Le Sueur)	Silver carp, carpsucker, coldwater carp
River carpsucker	*Carpiodes carpio* (Rafinesque)	Silver carp, carpsucker
Highfin sucker	*Carpiodes velifer* (Rafinesque)	Silver carp, river carp, carpsucker
White sucker	*Catostomus commersonnii* (Lacépède)	Common sucker, fine-scaled sucker
Spotted sucker	*Minytrema melanops* (Rafinesque)	Striped sucker
Silver redhorse	*Moxostoma anisurum* (Rafinesque)	Silver mullet
Northern redhorse	*Moxostoma aureolum* (Le Sueur)	Des Moines plunger, mullet, common redhorse

Carp	*Cyprinus carpio* Linnaeus	German carp, European carp
Golden shiner	*Notemigonus crysoleucas* (Mitchill)	American bream, roach
Channel catfish	*Ictalurus lacustris* (Walbaum)	Fiddler, catfish, channel cat, spotted cat
Blue catfish	*Ictalurus furcatus* (Le Sueur)	Fulton cat, Mississippi cat, chucklehead cat, coal boater
Yellow bullhead	*Ameiurus natalis* (Le Sueur)	Yellow-bellied cat, greaser
Brown bullhead	*Ameiurus nebulosus* (Le Sueur)	Speckled bullhead
Black bullhead	*Ameiurus melas* (Rafinesque)	Bullhead
Flathead catfish	*Pilodictis olivaris* (Rafinesque)	Hoosier, goujon, shovelnose cat, mudcat, yellow cat, Johnny cat, Morgan cat, flat belly
Pike	*Esox lucius* Linnaeus	Pickerel, great northern pike, northern pike, northern
Grass pickerel	*Esox vermiculatus* Le Sueur	Little pickerel, grass pike, mud pickerel
Yellow pikeperch	*Stizostedion vitreum vitreum* (Mitchill)	Walleye, jack, jack salmon
Sauger	*Stizostedion canadense* (Smith)	Sandpike, jack salmon
Smallmouth black bass	*Micropterus dolomieu* Lacépède	Smallmouth
Spotted black bass	*Micropterus punctulatus* (Rafinesque)	Kentucky bass
Largemouth black bass	*Micropterus salmoides* (Lacépède)	Black bass, bigmouth bass, line side, green bass, green trout
Green sunfish	*Lepomis cyanellus* Rafinesque	Black perch
Organgespotted sunfish	*Lepomis humilis* (Girard)	————
Bluegill	*Lepomis macrochirus* Rafinesque	Bream, sunfish
Warmouth	*Chaenobryttus coronarius* (Bartram)	Goggle-eye, warmouth bass
Flier	*Centrarchus macropterus* (Lacépède)	Round sunfish, longfinned sunfish, round bass
White crappie	*Pomoxis annularis* Rafinesque	Crappie, newlight
Black crappie	*Pomoxis nigro-maculatus* (Le Sueur)	Calico bass, strawberry bass
White bass	*Lepibema chrysops* (Rafinesque)	Silver bass, striped bass, streaker
Yellow bass	*Morone interrupta* Gill	Streaker, barfish
Freshwater drum	*Aplodinotus grunniens* Rafinesque	White perch, perch, sheepshead, gaspergou, grunting perch, croaker

* Because of the pressure of field work, most of the fish handled in the test-net collections could be classified only to species. Some, however, could be classified further, and the following subspecies are believed to have been represented in the sampling: *Lepisosteus osseus oxyurus* Rafinesque, northern longnose gar; *Carpiodes carpio carpio* (Rafinesque), northern carpsucker; *Catostomus commersonnii commersonnii* (Lacépède), white sucker, *Notemigonus crysoleucas auratus* (Rafinesque), western golden shiner; *Ictalurus lacustris punctatus* (Rafinesque), southern channel catfish; *Ictalurus furcatus furcatus* (Valenciennes), blue catfish; *Ameiurus natalis natalis* (Le Sueur), northern yellow bullhead; *Ameiurus nebulosus marmoratus* (Holbrook), brown bullhead; *Ameiurus melas melas* (Rafinesque), northern black bullhead; *Stizostedion canadense canadense* (Smith), eastern sauger; *Micropterus dolomieu dolomieu* Lacépède, northern smallmouth black bass; *Micropterus punctulatus punctulatus* (Rafinesque), northern spotted black bass; *Lepomis macrochirus macrochirus* Rafinesque, common bluegill. Accepted common and scientific names in the table are from Special Bulletin No. 1 of the American Fisheries Society (1948); most subspecific names in the footnote are from Hubbs & Lagler (1947).

only if the efficiency of the nets remained constant throughout the year could a just comparison on a pounds-per-net-day basis be made of the catches at various stations.

The seasonal activities and habitat preferences of various fishes complicate sampling with commercial gear. For example, a type of gear that is very effective for catching a certain species in the spring may be ineffective later in the year.

Throughout this investigation various types of gear were used and every effort was made to obtain a large catch at each station. To obtain large catches during the summer, it was usually necessary to increase the amount of fishing effort, table 1.

The composition of the catch at each station in the Caruthersville-Dubuque section of the Mississippi is presented in Appendix B. The data do not permit further valid statistical treatment. Difficulties encountered in netting preclude the assumption that a random sample was obtained.

Classification of Fishes

Among fishermen, the species of fishes found in the Mississippi River are known by many names. These names are often local in use and are of little value to fishermen or scientists working in another area. Among scientists, also, confusion of names exists. In an attempt to bring order out of the confusion of common and scientific names, the American Fisheries Society (1948) issued a special publication listing the generally accepted common and scientific names of the better-known fishes of the United States and Canada. In the present paper, most of the names—both common and scientific—adhere to those given in this special publication. The accepted common and scientific names and the widely used vernacular names of fishes taken in the Caruthersville-Dubuque survey are included in table 6.

The Mississippi River fishes of direct importance to man are treated as either commercial or sport fishes. It will be noted that certain species, particularly bullheads and other catfishes, included with the commercial fishes are also of importance to the sport fishery.

In the MR-C section of the river the mooneye (*Hiodon tergisus*) and the goldeye (*Amphiodon alosoides*) are of little importance commercially, whereas in parts of the D-MR section they are of some economic value. The data pertaining to these fishes are included in 1944 with the forage fishes and in 1946 with the commercial fishes. In tables where data are presented for both years, these fishes are considered as forage fishes.

The forage fishes may be defined usually as those of value only as food for other fishes. This group is composed largely of minnows (Cyprinidae); however, a member of the herring family, the gizzard shad (*Dorosoma cepedianum*), forms an important part of forage in the Mississippi River.

The gars (*Lepisosteus* spp.) and the bowfin (*Amia calva*) are not considered of sufficient commercial value to be included with the commercial fishes. They are regarded as a group known to prey upon other fishes and are presented as predators. Many of the other fishes, such as catfishes (Ameiuridae), black basses (*Micropterus* spp.), white bass (*Lepibema chrysops*), crappies (*Pomoxis* spp.), sauger (*Stizostedion canadense*), yellow pikeperch (*Stizostedion vitreum vitreum*), and pike (*Esox lucius*), are predatory fishes; however, superficially at least they are of more importance to man as commercial or sport fishes.

COMMERCIAL FISHES

Commercial fishes amounted to 76.4 per cent by weight of all fishes caught in the Caruthersville-Dubuque test-net survey of the Mississippi River. In 1946, the Mississippi River catch reported by commercial fishermen of Missouri, Iowa, and Illinois had a market value, based on local prices, of $396,824. If all the commercial fishermen of these states had reported all their Mississippi River catches and if the calculations had been based on prices actually received, rather than on local prices, the calculated value of the catch would have been higher. Many small operators who sold their fish locally did not report their catches, and many large operators shipped their fish to distant markets where they received prices higher than those prevailing in the local markets.

The species composition of the commercial catch in the Caruthersville-Dubuque

Table 7.—Commercial catches of some species of fishes from the Mississippi River for the years 1894, 1899, 1931, and 1946 as recorded for the states of Illinois, Missouri, and Iowa.* For purposes of comparison, catches are further expressed as per cents of the 1899 catch.

Year and State	Carp		Buffalo		Catfish and Bullhead		Freshwater Drum		Shovelnose Sturgeon		Lake Sturgeon		Paddlefish		Eel	
	Weight in Pounds	Per Cent of 1899 Catch	Weight in Pounds	Per Cent of 1899 Catch	Weight in Pounds	Per Cent of 1899 Catch	Weight in Pounds	Per Cent of 1899 Catch	Weight in Pounds	Per Cent of 1899 Catch	Weight in Pounds	Per Cent of 1899 Catch	Weight in Pounds	Per Cent of 1899 Catch	Weight in Pounds	Per Cent of 1899 Catch
1894																
Illinois	235.848	16.30	1,937,596	122.87	806,120	172.10	421,722	166.23	40,297	38.51	37,366	120.64	117,446	79.24	17,781	110.79
Missouri	47,289	11.31	1,178,745	154.41	546,986	157.42	163,665	143.25	30,189	39.82	37,877	521.08	106,976	100.38	6,241	191.68
Iowa	163,309	16.61	1,064,166	129.10	849,001	126.92	658,364	215.69	7,572	108.02	43,312	135.06	45,201	219.00	19,250	192.92
1899																
Illinois	1,446,698	100.00	1,576,998	100.00	468,403	100.00	253,696	100.00	104,644	100.00	30,974	100.00	148,216	100.00	16,050	100.00
Missouri	417,980	100.00	763,386	100.00	347,479	100.00	114,255	100.00	75,810	100.00	7,269	100.00	106,576	100.00	3,256	100.00
Iowa	983,305	100.00	824,291	100.00	668,935	100.00	305,230	100.00	7,010	100.00	32,068	100.00	20,640	100.00	9,978	100.00
1931																
Illinois	562,999	38.92	252,632	16.02	296,374	63.27	105,982	41.78	25,366	24.24	0	—	23,485	15.85	835	5.20
Missouri	265,005	63.40	112,140	14.69	†	—	26,845	23.50	14,239	18.78	0	—	37,388	35.08	1,055	32.40
Iowa	1,506,654	153.22	738,015	89.53	446,790	66.79	329,049	107.80	17,500	249.64	0	—	9,400	45.54	325	3.26
1946																
Illinois	792,250	54.76	398,515	25.27	259,686	55.44	173,429	68.36	12,493	11.94	0	—	26,853	18.12	‡	—
Missouri	217,909	52.13	83,255	10.91	†	—	55,432	48.52	4,361	5.75	0	—	10,213	9.58	566	17.38
Iowa	800,332	81.39	628,549	76.25	342,345	51.18	244,960	80.25	13,327	190.11	0	—	**	—	1,525	15.28

* 1894 (Smith 1898); 1899 (Townsend 1902); 1931 (Fiedler 1933); 1946 (unpublished records of the Illinois, Iowa, and Missouri conservation departments). The 1946 figures are based on yield reports submitted by commercial fishermen to their respective state conservation departments. The Iowa figure includes reports from more than 90 per cent of the state's licensed commercial fishermen, whereas the Illinois figure includes reports from only 26.5 per cent and the Missouri figure 55.5 per cent of the commercial fishermen of the respective states. Although the number of returns from the latter two states is small, it is believed that the statistics include most of the large operators and represent a large part of the actual catch.

† Channel catfish illegal to take commercially.

‡ No data.

** Illegal to take.

Table 8.—Commercial catches in pounds of the more important fishes from the Mississippi River at Lake Keokuk, or Pool No. 19 (Illinois and Iowa), and between the northern border of Illinois and Lake Keokuk (Illinois) for various years for which data are available, 1914–1946.*

Year	Lake Keokuk (Illinois and Iowa)						Northern Illinois Border to Lake Keokuk (Illinois)					
	Carp	Buffalo-fishes	Catfishes and Bullheads	Freshwater Drum	Paddlefish	Shovelnose Sturgeon	Carp	Buffalo-fishes	Catfishes and Bullheads	Freshwater Drum	Paddlefish	Shovelnose Sturgeon
1914	302.365	249,900	71,535	26,860	0	0	—	—	—	—	—	—
1917	762,259	696,543	109.904	160.554	927	0	—	—	—	—	—	—
1922	276,431	113.946	183,919	65.040	27,405	600	—	—	—	—	—	—
1927	291.199	67.872	140,343	27,538	1,249	0	—	—	—	—	—	—
1931	170.149	112.365	119,670	72,829	7,100	300	—	—	—	—	—	—
1932	209,750	82,500	87,500	91,750	1,300	1,100	456,500	183,100	148,700	139,500	500	2,400
1933	213,000	75,800	88.500	87.500	0	875	351.600	166,800	107,950	131,500	500	10,200
1934	352,500	84,600	108,500	133,500	14.400	0	396,800	183.300	162.600	199,700	2,100	7,000
1935	386,200	102,500	120,500	119.600	10,700	225	373.000	191,000	155,800	129,900	2,250	0
1936	480,200	131,000	184,800	127,400	4,400	0	623,200	334.700	237,700	167,800	2,100	1,000
1937	527,000	195,000	170,500	166,300	13,200	1.300	356,000	177.500	146,900	134,500	3,700	0
1938	348,700	112,400	70,200	77,300	2,400	0	359,400	197,200	94,100	104,100	0	0
1946	247,506	92,774	95.703	68,422	397	2,265	239,647	151.286	69,206	47,371	3,753	3,172

* 1914, 1917, 1922, and 1927 (Coker 1929); 1931 (Fiedler 1933); 1932 (Fiedler, Manning, & Johnson 1934); 1933 (Fiedler 1935); 1934 (Fiedler 1936); 1935 (Fiedler 1938*a*); 1936 (Fiedler 1938*b*); 1937 (Fiedler 1940); 1938 (Fiedler 1941); and 1946 (unpublished records of the Illinois and Iowa conservation departments, as explained in first footnote to table 7).

Table 9.—Species composition of Mississippi River commercial catches based on per cents of total weights published in commercial fishery reports for Illinois and Missouri for 1894, 1899, 1931, and 1946.*

Year and State	Per Cent Carp	Per Cent Buffalo-fishes	Per Cent Catfishes and Bullheads	Per Cent Fresh-water Drum	Per Cent Game Fishes	Per Cent Sturgeon	Per Cent Paddle-fish	Per Cent Pike	Per Cent Yellow Pike-perch and Sauger	Per Cent Miscellaneous†	Total Weight in Pounds
1894											
Illinois	5.93	48.70	20.26	10.60	2.53	1.95	2.95	0.25	0.45	6.39	3,978,731
Missouri	2.04	50.90	23.62	7.07	1.37	2.94	4.62	0.01	0.52	6.92	2,315,996
1899											
Illinois	33.43	36.44	10.82	5.86	2.78	3.13	3.42	0.13	0.35	3.64	4,327,766
Missouri	21.63	39.51	17.98	5.91	1.01	4.30	5.52	0.00	0.23	3.91	1,932,296
1931											
Illinois	44.02	19.75	23.17	8.29	Illegal‡	1.98	1.84	Illegal	Illegal	0.94	1,278,928
Missouri	49.08	20.77	9.81	4.97	Illegal	2.64	6.92	Illegal	Illegal	5.84	539,997
1946											
Illinois	46.19	23.24	15.14	10.11	Illegal	0.73	1.57	Illegal	Illegal	3.03	1,715,133
Missouri	49.14	18.78	13.03	12.50	Illegal	0.98	2.30	Illegal	Illegal	3.26	443,423

* 1894 (Smith 1898); 1899 (Townsend 1902); 1931 (Fiedler 1933); and 1946 (unpublished reports of the Illinois, Iowa, and Missouri conservation departments as explained in first footnote to table 7).

† The 1946 Illinois catch does not include the eel.

‡ Two hundred pounds of white bass reported by Fiedler (1933) are included in total weight figure for Illinois, 1931.

section of the Mississippi has changed considerably during the past 50 years. Commercial catch statistics relative to that section of the river bordering Missouri, Illinois, and Iowa are given in tables 7, 8, and 9. In 1894, carp (*Cyprinus carpio*) represented only 5.9 per cent by weight of the Mississippi River commercial catch by Illinois fishermen, table 9, whereas in 1946 carp amounted to 46.2 per cent of this catch. In 1894 the buffalofishes (Catostomidae) dominated the catch, as does the carp today. In table 7 the 1899 commercial report is used as a basis for interpreting trends in the catch of several commercial fishes. From these data it is apparent that the carp, buffalofishes, catfishes, and freshwater drum (*Aplodinotus grunniens*) have not been so greatly affected by man's modification of the river as have the paddlefish (*Polyodon spathula*), lake sturgeon (*Acipenser fulvescens*), and American eel (*Anguilla bostoniensis*).

The various species of buffalofishes and catfishes are difficult to distinguish, and commercial fishermen usually refer to them by local names, which sometimes are meaningless to fish technicians. This practice has necessitated that workers compiling statistics of commercial catches of Mississippi River fishes rely on the inclusive groupings of these fishes rather than on individual species. These fishes are discussed here on the basis of the inclusive groupings and their constituent species as determined during the survey.

Sturgeons

ACIPENSERIDAE

This family of fishes has a wide distribution in the northern parts of Asia, Europe, and North America. Some members are marine and ascend fresh-water rivers to spawn, whereas others are wholly confined to fresh water. Only three species of the seven known to occur in North American waters are found in the Caruthersville-Dubuque section of the Mississippi River.

The shovelnose sturgeon (*Scaphirhynchus platorynchus*) is now the only sturgeon of any commercial importance in the river. In 1946 a total of 30,181 pounds of this fish were reported as taken commercially from the Mississippi by Illinois, Iowa, and Missouri fishermen. As shown in table 7, the Mississippi River commercial catch of this sturgeon reported for Illinois and Missouri in 1946 was only 11.9 and 5.8 per cent, respectively, of the amounts reported for these states in 1899. The 1946 catch reported for Iowa was 190.1 per cent of the amount of the 1899 catch; however, it will be noted in table 7 that the 1899 catch for Iowa was very low as compared with that for Illinois and Missouri. From these statistics it must be concluded that the shovelnose sturgeon is much less abundant than it was prior to 1900.

It would be impossible to ascertain all of the contributing factors causing the decline of this fish. As determined by trammel netting, the shovelnose sturgeon is found most commonly over a sand or gravel bottom in the presence of some current. This type of habitat in the D-MR section of the Mississippi has been reduced by canalization and siltation. Several stomachs of the shovelnose sturgeon were examined from specimens taken at Andalusia and were found to contain mayfly nymphs of the genus *Hexagenia*. The siltation has reduced suitable habitats for many of the insect nymphs and larvae which form a part of the sturgeon diet. According to Coker (1930: 152), fish of this species were once considered a nuisance in the Mississippi and many of them were destroyed by fishermen when taken in nets.

Very little is known regarding the habits of the shovelnose sturgeon, and a lack of knowledge of this fish has been a handicap in formulating legislation to protect it.

In the Caruthersville-Dubuque survey all of the catches of shovelnose sturgeon, with the exception of one, were taken by trammel-net floating. As tables 2 and 3 indicate, no trammel-net floating was done below the mouth of the Missouri River, which apparently explains the absence of the shovelnose sturgeon from catches in the MR-C section. That this sturgeon still is present in this section is evidenced by commercial reports and by specimens seen during the survey. At Hickman, Kentucky, in 1944, fishermen were seen catching shovelnose sturgeons on trotlines baited with worms. In the section of the

Table 10.—Length-frequency distribution, average lengths,* and average weights of shovelnose sturgeons taken from the Mississippi River at Burlington, Iowa, and Andalusia, Illinois, in 1946.

Standard Length in Inches	Burlington, Iowa† April 12, 1946	Andalusia, Ill. April, 1946	Andalusia, Ill. June, 1946	Andalusia, Ill. September, 1946	Total
13 8–14 7	—	—	1	—	1
14 8–15 7	—	—	—	1	1
15 8–16.7	—	1	—	6	7
16 8–17.7	—	1	—	5	6
17 8–18–7	—	5	—	1	6
18.8–19.7	2	11	3	4	20
19.8–20.7	2	7	8	5	22
20.8–21.7	3	18	6	9	36
21.8–22.7	—	18	7	12	37
22.8–23 7	3	22	11	6	42
23.8–24.7	9	18	5	13	45
24 8–25 7	2	18	3	7	30
25.8–26 7	4	11	4	3	22
26.8–27.7	2	7	2	1	12
27.8–28.7	1	5	3	3	12
28.8–29.7	—	1	2	—	3
29 8–30 7	—	1	1	1	3
30 8–31 7	—	2	—	—	2
31.8–32 7	2	—	—	—	2
32 8–33 7	—	1	—	—	1
Total number	*30*	*147*	*56*	*77*	*310*
Average length	24 5	23.4	23.3	22.2	23.2
Average weight in pounds	1 69	1 34	1.45	1.07	1.33

* Length from tip of snout to base of caudal filament.
† The specimens were taken near Burlington by J. O. Kurrle, a commercial fisherman.

river between Burlington and Dubuque the shovelnose sturgeon amounted to 2.6 per cent by weight of the total catch. This figure indicates that the species is not scarce in this section of the river and that it is able to maintain itself in spite of canalization. The commercial take of this species for intermittent years, 1914 through 1946, at Lake Keokuk (Pool No. 19) and, 1932 through 1946, in that part of the river between Lake Keokuk and the northern border of Illinois is given in table 8. For the years included in this table the shovelnose sturgeon formed only a small portion of the commercial catch.

Sex determinations were made of 307 of the 310 shovelnose sturgeons caught in 1946. In April the males predominated in the collections taken in the channel of the river by trammel-net floating. During this month males made up 93 per cent of the catch of this species at Burlington and 99 per cent at Andalusia. At Andalusia in June males represented only 41 per cent of the catch and in September 57 per cent. The predominance of males in the channel in April indicates that the females seek another habitat during this season, returning to the channel by June. According to Harry E. Finley, a commercial fisherman at Andalusia, female shovelnose sturgeons are seldom taken by commercial fishermen during April and May, which he believes are the months of the spawning season. During this period, in his opinion, the females seek cover and consequently do not occur in the open water of the channel where trammel nets are normally drifted.

Observations on size and condition of gonads of the shovelnose sturgeon indicate that the males reach maturity at lengths of 19.5 to 22 inches (standard length, which is length from tip of snout to base of caudal filament); the smallest mature female examined was 25 inches in length. The length-frequency distribution of the fishes taken at Burlington and Andalusia, table 10, indicates that trammel nets catch many sturgeons less than 25 inches in

length. The adoption of a legal minimum length of 25 inches would afford some protection to immature shovelnose sturgeons.

The average weight of shovelnose sturgeons taken during the survey was only 1.3 pounds (excluding the Burlington catch). Fish of this species are not known to attain such great weights as the lake sturgeon.

The fishery statistics for 1894 and 1899, table 7, indicate that the lake sturgeon (*Acipenser fulvescens*) was once rather common in the Mississippi River. Forbes & Richardson (1920: 25), writing in 1908 or before, stated that this species was steadily decreasing and only rarely was taken in the Mississippi on the borders of Illinois. No lake sturgeon was caught in the test nets in 1944 or 1946. A lake sturgeon weighing 32 pounds was taken May 6, 1946, in a hoop net of a commercial fisherman at New Boston, Illinois. This was the only specimen of this species observed by the work party during the 2 years of the field investigation. The lake sturgeon is now taken only occasionally by commercial fishermen of the area.

More than 45 years ago, Forbes & Richardson (1905:38) described as *Parascaphirhynchus albus* a species of sturgeon taken from the Mississippi River near Alton and Grafton. They gave it the common name white sturgeon, the term by which it was known to fishermen of the locality. Later, Forbes & Richardson (1920: 29) stated that this sturgeon was known to them only from the Mississippi River at Grafton and Alton, where it was rare, but that it was said by a commercial fisherman to be somewhat commoner in the lower part of the Missouri.

In 1944 one specimen of this species was procured from an angler fishing in the Mississippi River just above the mouth of the Missouri. It weighed only 0.12 pound. According to fishermen in the Alton area, fish of this species are taken occasionally by them along with the shovelnose sturgeon. These fish are not known from the Mississippi other than near its confluence with the Missouri. The specimen mentioned above was the only one of this species observed between Caruthersville and Dubuque.

This specimen was submitted for identification to Dr. Reeve M. Bailey of the University of Michigan Museum of Zoology who (personal communication) determined it as *Scaphirhynchus album* (Forbes & Richardson). The species is at present without a recognized common name. The term white sturgeon is recognized (American Fisheries Society 1948) as the common name for *Acipenser transmontanus*, with which the species of the Mississippi River should not be confused. To Mississippi River fishermen *S. album* is known as the white hackleback and the white shovelnose, as well as the white sturgeon. Dr. Bailey (personal communication) recently suggested the vernacular name pallid sturgeon for *S. album*.

Paddlefish

POLYODONTIDAE

This interesting fish was recorded by the first white expedition that reached the Mississippi River. Nuttall (1821: 254) mentioned that at Pacaha members of the De Soto expedition, fishing with nets, included in their catch "the Pele-fish, destitute of scales, and with the upper jaw extended in front a foot in length, in the form of a peel or spatula." Jefferson (1801: 12) included in his list of Mississippi River fishes a spatula-fish of 50 pounds weight.

The paddlefish, which is often referred to as the spoonbill cat by commercial fishermen, has long attracted the attention of zoologists. The skeleton of this primitive fish is largely of cartilage, and the external appearance of the fish is quite sharklike. The paddlefish family (Polyodontidae) is composed of only two genera, each containing a single species, one found in China, the other in North America (Forbes & Richardson 1920: 15). The North American species is limited in distribution to the Mississippi basin and other tributaries of the Gulf of Mexico (Coker 1930: 142). According to Eddy & Surber (1947: 74), the paddlefish once ranged in the quiet waters of the Mississippi River from Minneapolis to the Gulf; it is now much more abundant in the southern part of its range than farther north. In the Caruthersville-Dubuque survey the paddlefish was not taken above Canton; however, in 1946 a commercial catch of 1,204 pounds was taken in one seine haul near

New Boston. Many of these specimens were examined by the survey party and the data and gonad material were assigned to Dr. R. Weldon Larimore of the Illinois Natural History Survey for histological study. Paddlefish were caught at 40 per cent of the stations below the mouth of the Missouri River and 42 per cent of the stations between the mouth of the Missouri and Warsaw. Fish of this species were usually taken with a seine, and the average weight of specimens was 2.17 pounds.

On August 19, 1944, at the Cincinnati Landing station, a large school of paddlefish was sighted by the survey crew at about 5 P. M. These fish appeared to be large and apparently were feeding in the shallow water over sand bottom. They were swimming so near the surface that the tailfins of the larger ones extended several inches above the water, and, as they swam about in what appeared to be an aimless manner, some of them frequently thrust their paddles above the surface. Plans were immediately made to seine the area; however, before a seine could be obtained a half hour had elapsed and, much to the disappointment of the crew, the large school had completely vanished.

At the Quincy and New Boston stations paddlefish were observed traveling in schools and feeding in shallow water over sand bottom. In the canalized section of the river this type of habitat is largely confined to the upper sections of the pools. In all catches and observations made during the survey the paddlefish was associated with sand bottom.

At the Cape Girardeau station on May 29, 1944, four specimens of a post-larval stage of paddlefish were taken along the sandy shore of an island. The post-larval forms collected by Thompson (1933:31) near Grand Tower, Illinois, in May, 1932, also were taken over a hard sand bottom.

In 1946 the commercial value of paddlefish in the round was 15 cents per pound. About 20 years ago Coker (1930: 142) stated that the roe of the paddlefish was sometimes worth more than $2.00 a pound and that a large female might have considerable value, as its roe might weigh 10 to 15 pounds. Since 1899 the commercial take of paddlefish in the upper Mississippi has decreased considerably, as shown in tables 7, 8, and 9. This species in the Caruthersville-Dubuque section is becoming relatively scarce. It has been placed on the protected list by the state of Iowa in the hope that its abundance will be increased. If full protection were rendered the paddlefish, it probably would continue to be reduced in numbers by commercial fishermen since this fish often dies after being handled.

American Eel

ANGUILLIDAE

The American eel spawns in the sea. The young eels ascend rivers and streams where they remain for several years. Upon reaching mature size, they return to the sea where they spawn and die.

According to Eddy & Surber (1947: 192) the American eel was at one time fairly common up the Mississippi River at least as far as St. Anthony Falls, Minnesota, but it has now become almost extinct in Minnesota and Wisconsin. These writers stated that the dams on the river are undoubtedly responsible for the scarcity of the eel in the upper Mississippi. The commercial reports show a decline in the eel fishery in the Illinois-Iowa-Missouri section of the Mississippi since 1894, table 7. Even in 1894 this fishery was small, the recorded commercial catch amounting to only 43,272 pounds. In 1931 the catch was only 2,215 pounds. In 1946 very few eels were taken commercially in the section of the river adjacent to Missouri. In that year the largest recorded catch was in the canalized Iowa section; no catch data for Illinois were available.

Coker (1930:173) concluded from his studies at Lake Keokuk that the eel must virtually disappear from the Mississippi River and tributaries above the Keokuk dam (Lock and Dam No. 19). He mentioned that the eel had been decreasing steadily for 30 years in the Mississippi and he was unable to attribute the decline to a single cause, particularly since the decline started prior to the construction of the Keokuk Dam, practically completed in 1913.

In the Caruthersville-Dubuque survey, eels were taken at a larger percentage of

the stations above the mouth of the Missouri River than below. In the canalized section of the river between Burlington and Dubuque, eels amounted to 0.1 per cent of the total number of fishes taken; below the mouth of the Missouri, 0.2 per cent. At Dubuque, the uppermost station on the river, three eels were taken weighing a total of 9.1 pounds. At the Hannibal station six eels were caught; this was the largest number taken at a single station. This station was situated in Pool No. 22, which is above four locks and dams. The eel, as evidenced by these catches, moves upstream into the canalized section even though its passage is hindered by a series of locks and dams. On the basis of this investigation, the eel appears not to be common anywhere in the river, and its scarcity is such as to make it of little or no commercial importance.

Suckers and Redhorses

CATOSTOMIDAE

The fishes in this family, other than the carpsuckers, are too scarce to be of much commercial importance in the Caruthersville-Dubuque section of the Mississippi. The carpsuckers (*Carpiodes* spp.) constituted one of the more abundant groups of fishes taken during the survey. They were taken at all stations, usually in considerable numbers. Because of the difficulties encountered in the separation of the species of carpsuckers, no attempt was made to distinguish the species afield. Names of the three species identified from the collections are listed in table 6. Carpsuckers amounted to 7.2 per cent of the total weight of the 1944 catch between Caruthersville and Warsaw and 14.2 per cent of the total weight of the 1946 catch between Burlington and Dubuque, Appendix B.

At Keokuk, Coker (1930: 184) found the river carpsucker (*Carpiodes carpio*) the only carpsucker constituting a notable fishery product. The commercial fishery statistics pertaining to the 1946 Mississippi River catch of Illinois, Iowa, and Missouri indicate that in total weight the carpsuckers ranked fifth. The catch of carpsuckers in the test-netting survey indicates that these fish form a larger percentage of the catch than is shown by the commercial statistics. In the canalized section of the river between Burlington and Dubuque, the three species of carpsuckers ranked second by weight in the test-net catches, and in the lower section of the river they ranked third, Appendix B. During these 2 years the average weight of carpsuckers was 1.24 pounds. According to Coker (1930: 185) carpsuckers of substantial size (above 4 pounds) are considered of commercial value, "usually selling as No. 1 fish, some others selling as No. 2 fish, and still others being thrown away." Because of this large size requirement, and because the flesh of carpsuckers is favorless and soft (Forbes & Richardson 1920: 77) and is said not to keep well in warm weather (Coker 1930: 184), many of the carpsuckers actually taken are not marketed and therefore do not appear in the commercial reports. Methods of processing for better utilization of the carpsuckers are sorely needed on the Mississippi as well as on other large rivers in the central states.

Forbes & Richardson (1920:66), about 50 years ago, found that the blue sucker (*Cycleptus elongatus*) was confined to the Ohio and Mississippi rivers and some of its tributaries. In the Mississippi they rarely found this sucker above Quincy at the time of their survey. However, several years later Greene (1935:57) mentioned that the blue sucker was reported to be common in the river near Lansing, Iowa, which is about 337 miles above Quincy, and Coker (1930: 182) cited "oral reports of fishermen at many points on the Mississippi, as far north as Wisconsin, that until 10 or 15 years ago there were important spring runs and lesser fall runs of blue suckers." In the spring, blue suckers formerly were caught quite easily by commercial fishermen. These catches were made in the swifter parts of the river. By 1926, however, according to Coker (1930: 183), commercial fishermen held an almost unanimous opinion that the blue sucker had virtually disappeared from the upper river. That same year Coker encountered practically no fishermen in the Keokuk area who had seen more than two or three blue suckers a year.

In the Caruthersville-Dubuque survey the blue sucker was taken infrequently. No adult blue sucker was caught in the

MR-C section of the river, although at the Cairo station 28 small blue suckers were taken with a minnow seine. Forbes & Richardson (1920: 66) noted in the early part of this century that the blue sucker frequently was taken in the Cairo area during the spring. This species was nôt abundant enough at the time of the survey to be of any commercial importance in the Cairo area, even though it still occurred there.

On April 11, 1951, Herbert J. Fisher of the Missouri Conservation Commission and the junior author examined five blue suckers at Bennett Brothers' fish market at Ste. Genevieve, Missouri. The fishermen had caught about 100 pounds of this species in hoop nets on April 10 and 11.

All specimens of this sucker taken by the survey party in the D-MR section of the river were caught at or above the Cincinnati Landing station. At this station in August, 1944, an adult blue sucker weighing 2.8 pounds was caught in a test net set in a small slough. The flow into this slough passed over a rock wing-dam at the head of an island. The slough was approximately 150 yards in width, and the current was moderately swift over a sand bottom. At the Canton station two blue suckers weighing in aggregate 3.62 pounds were taken in test nets. Only five blue suckers were taken in the 1946 collections between Burlington and Dubuque, Appendix B, table 2. The scarcity of the blue sucker in the Caruthersville-Dubuque section of the river as shown by the test-net collections confirms the pessimistic opinions of commercial fishermen concerning the present status of this fish.

The removal of the Le Claire and Keokuk rapids in the river and construction of the Keokuk Dam have been considered as factors contributing to the decline of the blue sucker population in the D-MR section of the river. According to Coker (1930: 184, 187), however, the blue sucker also declined in the MR-C section of the river—indicating that some other factor or factors contributed to its decline.

The northern redhorse (*Moxostoma aureolum*) was netted more frequently than the silver redhorse (*Moxostoma anisurum*), the only other species of redhorse taken in the test-net survey. It appeared in the collection at only one station in the MR-C section of the river, whereas it was taken at all stations above Burlington in the D-MR section. The largest catches of the northern redhorse were made at the Bellevue station, where they amounted to 15.9 per cent of the total weight of all fish taken there.

In the Burlington-Dubuque section the total weight of the northern redhorse catch was 1.5 per cent of the total catch for the section. In the section between Burlington and the mouth of the Missouri, the northern redhorse amounted to only 0.27 per cent of the total weight of the catch there. These data indicate that the northern redhorse is more abundant in the river above Burlington than below.

The commercial fishery statistics for suckers in the Mississippi basin show a sharp decline since 1899 (Coker 1930: 187). The various species of redhorses and suckers are now too scarce in the Caruthersville-Dubuque section of the river to be of commercial importance.

Buffalofishes

CATOSTOMIDAE

Three species of buffalofishes occur in the Caruthersville-Dubuque section of the Mississippi River. In aggregate, these fishes now rank second to carp in the Mississippi River commercial fishery catch of Illinois, Iowa, and Missouri. Prior to the appearance of the carp, the buffalofishes comprised the largest part of the commercial catch. In 1894 the buffalofishes constituted 48.7 per cent of the weight of the Illinois catch in the Mississippi River and 50.9 per cent of the Missouri catch in the Mississippi, table 9. In 1899 the catch of buffalofishes still held a weight advantage over the catch of carp, which by that year were becoming very abundant in the river.

As shown in table 8, the catch of carp at Lake Keokuk (Pool No. 19) in 1914 exceeded that of buffalofishes by more than 50,000 pounds.

At Lake Keokuk the carp made its greatest gains over the buffalofishes between 1922 and 1927. By 1931 the buffalofishes represented only 19.8 per cent of the weight of the Mississippi River catch by Illinois commercial fishermen and 20.8 per

cent of that by Missouri fishermen, table 9. Commercial catches of buffalofishes in that part of the Mississippi bordering Illinois, Iowa, and Missouri have been much smaller in most recent years than in years previous to 1900; however, the decrease in catch, as shown by 1946 figures in table 7, has not been so great as to cause alarm. Commercial reports indicate that the buffalofish catches in Iowa have remained high and have decreased only slightly below the 1899 catch. In 1950 the Mississippi River catch of buffalofishes by commercial fishermen of Illinois was larger than the catch of carp and amounted to 36.6 per cent of the total commercial catch from the Mississippi by these fishermen.

During the past 50 years extensive levee and drainage districts have been developed in the MR-C section of the river—more extensive than in the D-MR section. The development in the lower section has resulted in a scarcity of backwaters and sloughs attached to this section. The buffalofishes are known to use backwaters and sloughs for spawning grounds, and perhaps the reduction of such areas in the lower section accounts for much of the decrease in the buffalo fishery there during the past half century. At Lake Keokuk (Pool No. 19) Coker (1930:194) noted an upward trend in the commercial take of buffalofishes in 1917 and a discouraging decline in 1922. Between these years, Coker writes, extensive areas evidently suitable for spawning and nursery purposes were reclaimed for farming. In table 8 the commercial catches from Lake Keokuk are given for several years. The catches of buffalofishes from this impoundment have never recovered since connecting shallow waters were reclaimed for agricultural purposes.

The buffalofishes ranked fourth in total weight among the commercial fishes taken in the test-net collections, fig. 7, rather than second as might be expected from the commercial fishery statistics. This difference in rank was due probably to fishing effort and type of gear employed and to the inclusion in survey data of all carpsuckers taken during the survey; carpsuckers are a group of fishes not invariably reported by commercial fishermen.

The average weight of buffalofishes taken between Caruthersville and Warsaw in 1944 was 1.65 pounds; between Burlington and Dubuque in 1946 it was 1.78 pounds. The over-all average was 1.72 pounds.

On a numerical basis the buffalofishes ranked fifth among the commercial fishes taken in the test-net collections, fig. 7.

In the commercial statistics, for reasons previously discussed, the catches of the three species of buffalofishes are presented in aggregate. An attempt has been made to appraise the relative abundance of the three species and their distribution in the MR-C and D-MR sections of the river, fig. 8. Such information should be of value in the management of the buffalo fishery. The meager information concerning these fishes indicates the existence of certain differences in the habits of the three species.

The black buffalo (*Ictiobus niger*) was taken in greater numbers in the collections from the MR-C section than in those from the D-MR section of the river, fig. 8. Coker (1930:191) noted that the black buffalo (bugler) was chiefly southern in distribution and that at the time of his study it was not abundant in the river above Muscatine. He found that it appeared "rather prominently in the region of New Boston and southward," and just below Keokuk it seemed to rank in abundance with the smallmouth buffalo or roachback (*Ictiobus bubalus*).

At the Warsaw station, which was below Keokuk, the buffalo test-net catch in 1944 was predominantly smallmouth, Appendix B, table 1. Here 59 specimens of the smallmouth buffalo were taken in contrast to 1 specimen of the black buffalo and 3 of the bigmouth buffalo (*Megastomatobus cyprinella*). At Caruthersville no black buffaloes were taken in the survey nets; however, according to a Mr. Boyer, a local commercial fisherman, this species and the other buffalofishes usually are taken in catches in about equal numbers. One black buffalo weighing 19.5 pounds was examined from a commercial fisherman's catch at Caruthersville. The average weight of the black buffaloes taken in the survey was 4.06 pounds, an average much greater than that of the other species of buffalofishes.

The bigmouth buffalo appeared to be more abundant than the black buffalo. However, the average weight of the big-

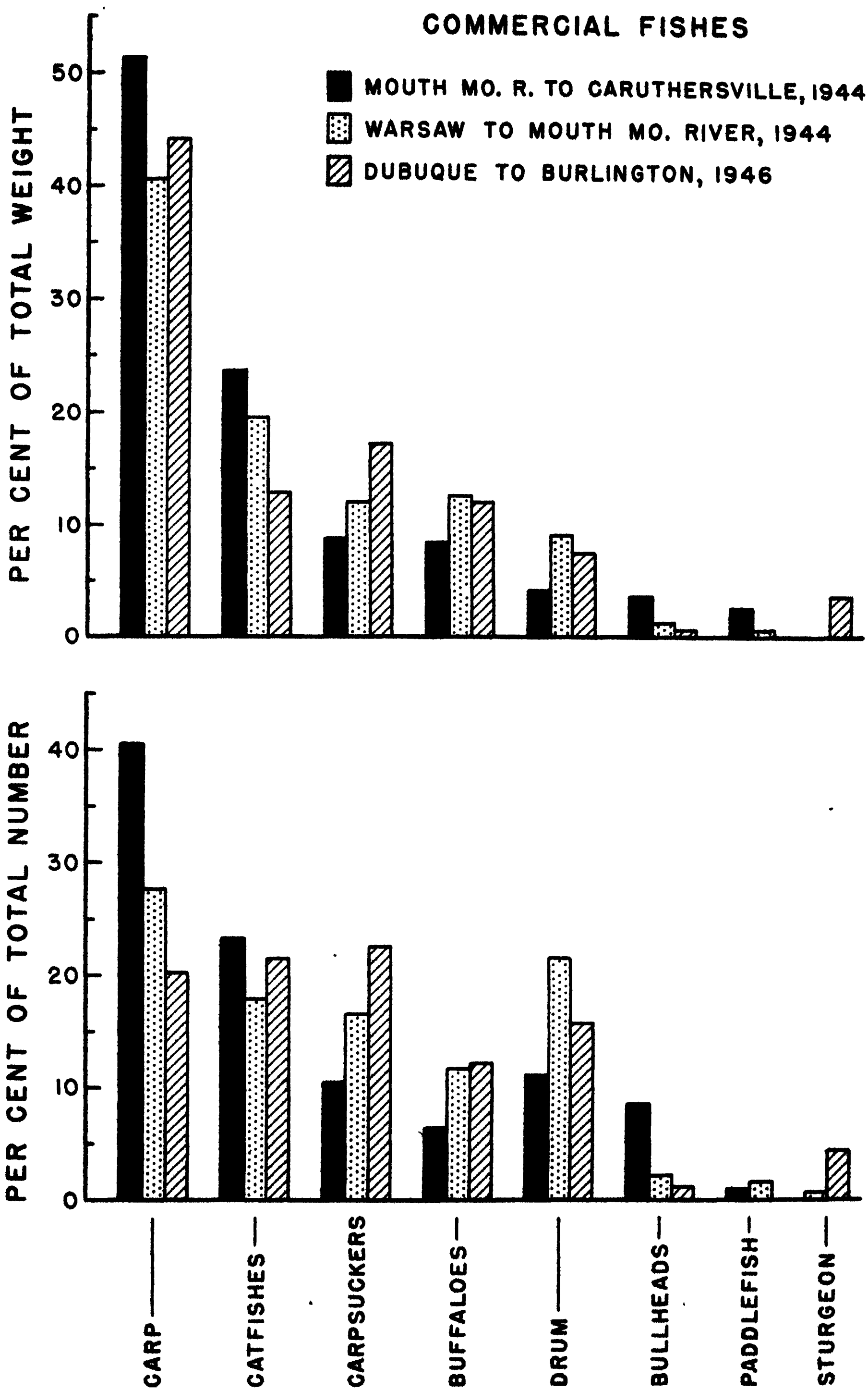

Fig. 7.—The relative abundance and the relative weight of each of various commercial fish groups taken in the test-net collections from three sections of the Mississippi River, 1944 and 1946.

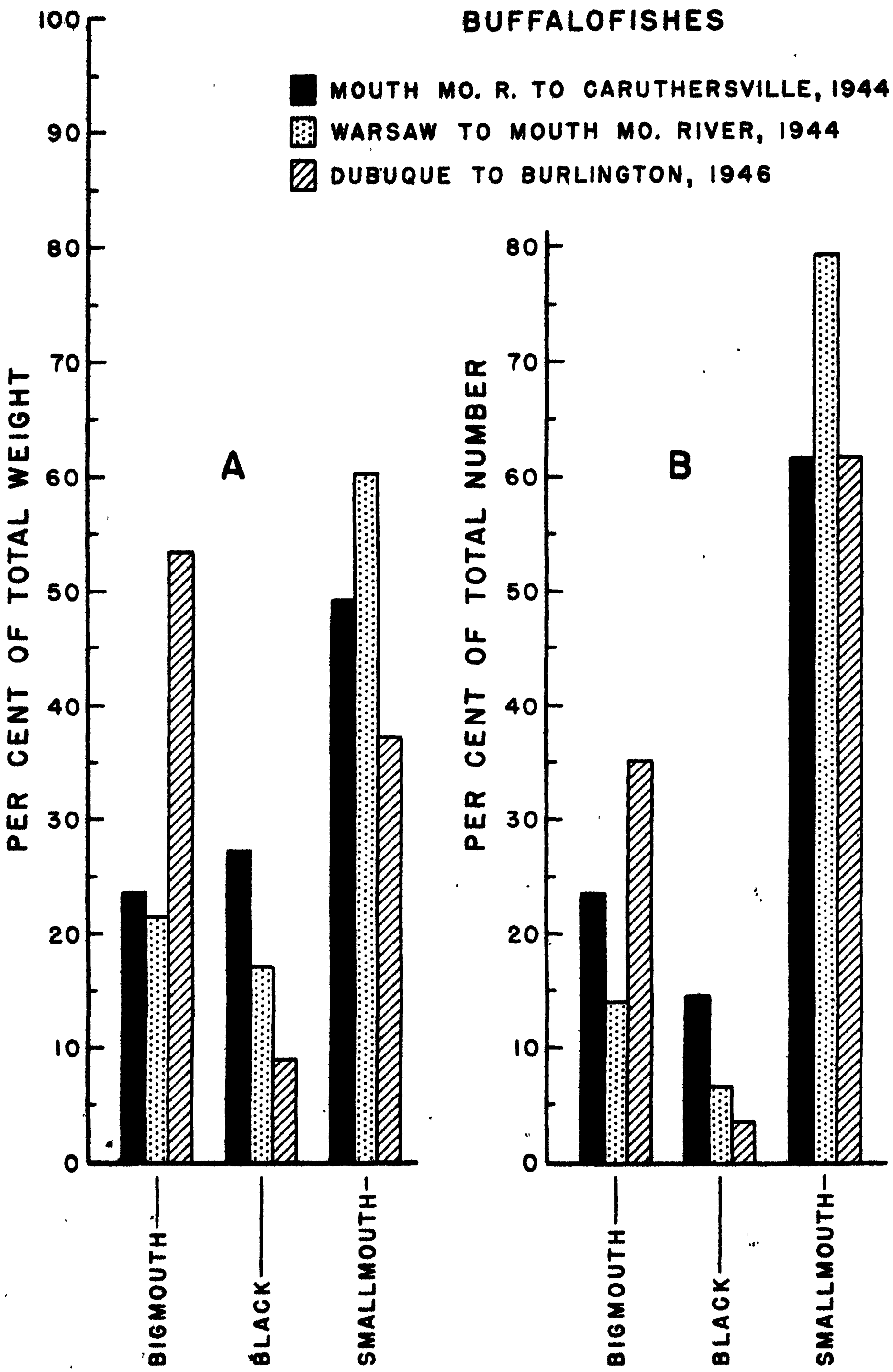

Fig. 8.—The relative weight and the relative abundance of each of three species of buffalofishes taken in the test-net collections from three sections of the Mississippi River, 1944 and 1946.

mouth collected was 2.57 pounds, much less than that of the black buffalo.

The smallmouth buffalo was by far the most abundant buffalofish taken in the survey; however, the average weight of 1.17 pounds for this species was considerably less than that for the other species. From a study of fig. 8, it becomes quite evident that on a weight basis the smallmouth buffalo was dominant in the survey catches in the MR-C section and that part of the D-MR section investigated in 1944, and that the bigmouth buffalo dominated the 1946 catches, which were in the Burlington-Dubuque section of the river. Numerically, the smallmouth buffalo dominated the collections in all three sections of the river referred to in fig. 8.

The average lengths of the black buffalo and the bigmouth buffalo in the test-net collections were greater than the average length of the smallmouth buffalo, table 11.

Examination of a large number of specimens indicated that the smallmouth buffalo and the bigmouth buffalo become sexually mature at about 15 inches in length. So few specimens of black buffalo were examined that maturity size for this species was not determined; the smallest ripe female noted was 18.5 inches long.

In the test-net collections only 24 per cent of the smallmouth buffaloes but 75 per cent of the other buffalofishes equaled or exceeded 15 inches in length. Commercial fishermen using nets of legal mesh

Table 11.—Length-frequency distribution of buffalofishes (most of them in test-net collections) from the Mississippi River between Caruthersville, Missouri, and Dubuque, Iowa, in 1944 and 1946.

Total Length in Inches	Smallmouth Buffalo			Black Buffalo*			Bigmouth Buffalo		
	MR–C Section 1944	D–MR Section 1944	D–MR Section 1946	MR–C Section 1944	D–MR Section 1944	D–MR Section 1946	MR–C Section 1944	D–MR Section 1944	D–MR Section 1946
3.8–4.7	—	—	24	—	—	—	—	—	1
4.8–5.7	3	4	30	2	—	—	1	—	1
5.8–6.7	7	5	21	—	—	—	—	1	3
6.8–7.7	7	14	36	—	—	—	1	1	1
7.8–8.7	5	29	56	3	—	1	1	—	2
8.8–9.7	16	26	34	—	—	—	1	1	2
9.8–10.7	16	44	22	1	1	—	1	2	4
10.8–11.7	17	63	25	1	—	1	6	1	6
11.8–12.7	4	48	28	1	2	—	14	1	5
12.8–13.7	10	36	40	1	2	1	6	3	10
13.8–14.7	7	15	50	3	3	1	2	12	12
14.8–15.7	5	20	61	1	1	4	—	7	31
15.8–16.7	4	13	36	1	4	2	2	16	63
16.8–17.7	6	10	18	2	4	2	3	9	47
17.8–18.7	9	6	15	—	3	1	—	4	50
18.8–19.7	3	3	1	1	2	5	1	2	25
19.8–20.7	2	2	3	3	—	1	3	—	25
20.8–21.7	2	—	1	1	2	4	3	—	4
21.8–22.7	1	1	—	—	1	1	2	—	1
22.8–23.7	—	—	—	3	2	1	1	1	1
23.8–24.7	—	2	—	5	—	5	—	—	—
24.8–25.7	—	—	1	—	—	3	—	—	1
25.8–26.7	—	—	2	—	—	1	—	—	—
26.8–27.7	—	—	—	1	1	—	—	—	—
27.8–28.7	1	—	1	—	—	1	—	—	—
28.8–29.7	—	—	—	—	—	1	—	—	—
29.8–30.7	1	—	—	—	—	1	—	—	—
30.8–31.7	—	—	—	—	—	—	—	—	—
31.8–32.7	1	—	—	—	—	—	—	—	—
Total number	*127*	*341*	*505*	*30*	*28*	*37*	*48*	*61*	*295*
Average length	12.6	11.8	11.6	17.0	17.3	20.3	14.2	15.3	16.6

* The D-MR 1946 data include 19 specimens of smallmouth buffalo, 8 of black buffalo, and 18 of bigmouth buffalo caught with commercial gear by J. O. Kurrle in the Burlington area.

sizes catch a higher percentage of smallmouth buffaloes of 15 inches or more in length than was taken in this investigation, in which some nets of smaller mesh sizes were used.

Carp

CYPRINIDAE

The carp is a native of neither Europe nor America. According to Hessel (1878: 865–6), in all probability it was introduced into Europe from Central Asia many centuries ago. Europeans have reared and cultivated it at least since 1227, and they consider it as an excellent food fish. During the nineteenth century many of our forefathers, then recent immigrants from Europe, clamored for the introduction of carp into North America. Various attempts evidently were made in carp plantings; in 1877 the United States Fish Commission was successful in importing a shipment of 345 carp, of which 227 were of the mirror and leather varieties. These carp were released in ponds at Washington, D. C., where they multiplied rapidly. In 1879, 12,000 young produced in the Washington ponds were distributed among more than 300 persons in 25 states and territories (Forbes & Richardson 1920:105).

Carp apparently were not planted directly by man into the Mississippi but escaped from nearby carp ponds during floods. Reports of carp in the Caruthersville-Dubuque section of the Mississippi came in 1883 from Hannibal, Missouri, and Quincy, Illinois (Cole 1905:549). Garman (1890:143) studied the fish fauna of the Mississippi bottoms near Quincy in August, 1888, and from his observations there wrote the following regarding the carp: "This hardy fish seems destined to become a permanent part of our fauna." In this 1888 investigation Garman found the carp widely distributed throughout the bottomland lakes.

The carp did not increase in the commercial catch of the Mississippi as rapidly as in its more productive tributary, the Illinois River. In 1899 nearly six times as many pounds of carp were taken from the Illinois River as were taken by Illinois commercial fishermen from the Mississippi (Townsend 1902:681).

The commercial statistics in tables 7 and 9 reveal the importance of the carp in the Mississippi River commercial fishery. The carp is now the most important commercial fish in the river and it would be only a matter of speculation as to what the size of the catch of the other fishes would be if carp were not in the present fauna.

The survey catch of carp in 1944 and 1946 was high at most of the stations, ranging from 12 to 70 per cent by weight of the catch of all the commercial fishes. Fig. 7, in which the catch of carp is presented as a per cent of the total weight of the commercial fishes caught in the test nets, demonstrates the significance of the carp to the commercial fishery. The carp was by far the most important commercial species, as such groups as catfishes, carpsuckers, and buffalofishes are composed of more than one species. The position of the carp in relation to all fishes taken at the several survey stations is shown graphically in fig. 9.

In fishery management the size and age of the fishes comprising the catch are basic to an analysis of the condition of a fishery. The average lengths and weights of carp taken by test netting at the various stations were recorded and are given in table 12. Carp have been reported from Europe as attaining weights of 42 to 67 pounds (Hessel 1878:874) and some of the scales from a 67-pound fish were said to measure 2.5 inches in diameter. Occasionally carp weighing 25 to 35 pounds are taken by commercial fishermen from the Mississippi; however, the average weight of the carp appearing in the survey catch was 2.65 pounds.

The difference between the average weights of the carp taken in 1944 and the average weights of those taken in 1946 appears by inspection of table 12 to be associated with the presence of relatively few small carp in the 1946 collections and relatively large numbers of small ones in 1944. A difference of this kind might be expected in any population after a lapse of 2 years and might be the result of differential survival of year classes.

The difficulties involved in attempting to determine by the scale method the age of summer-caught carp from a heterogeneous carp population composed of a

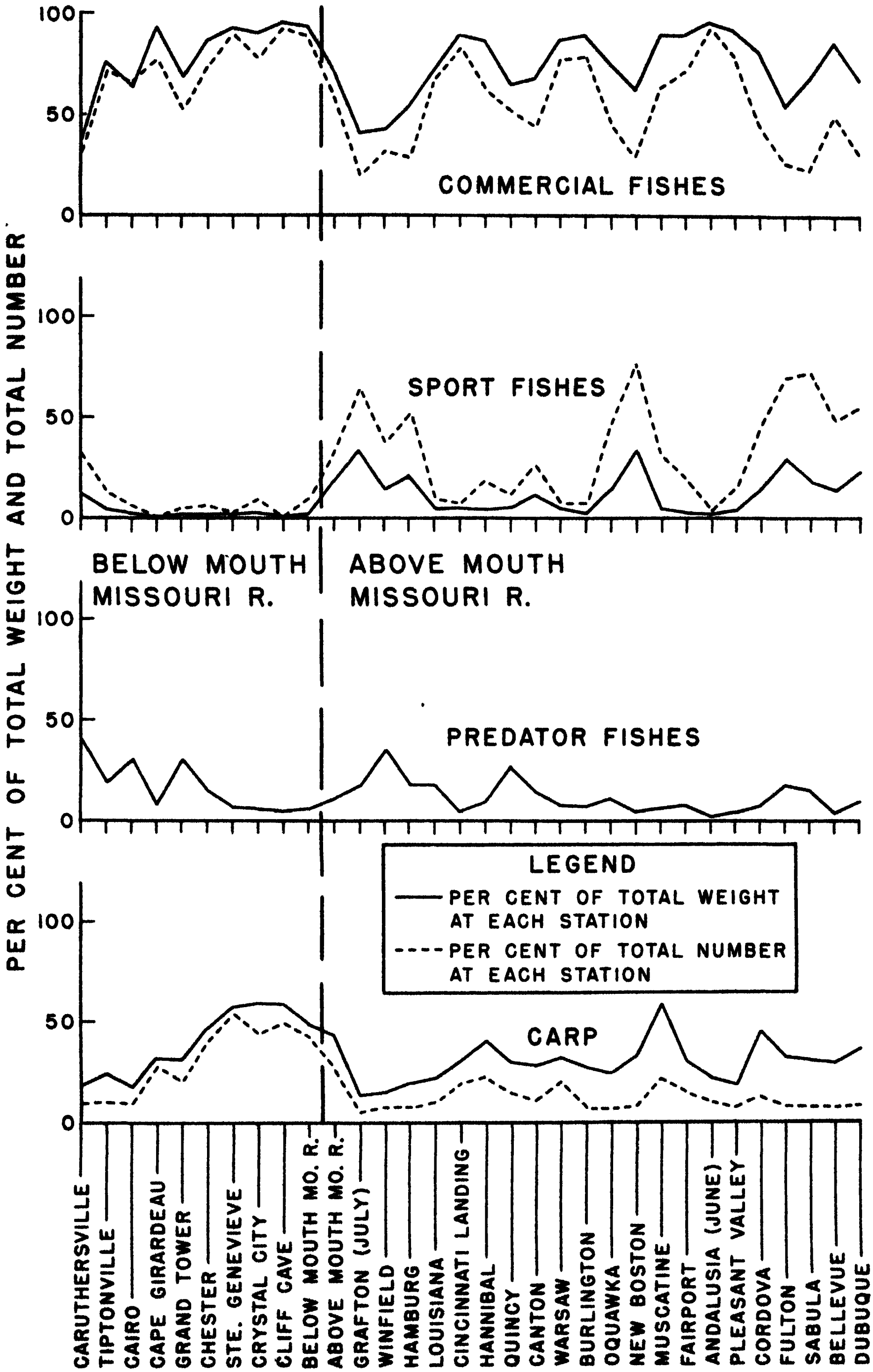

Fig. 9.—The relative weight and the relative abundance of each of several groups of fishes taken in test-net collections in the Caruthersville-Dubuque section of the Mississippi River. The curves are based on the per cents of total weight and of total number of all the fish collected at each station. Sampling was conducted at stations between Caruthersville and Warsaw in 1944 and between Burlington and Dubuque in 1946.

Table 12.—Length-frequency distribution and average lengths and weights of carp in test-net collections from the Mississippi River between Caruthersville, Missouri, and Dubuque, Iowa, in 1944 and 1946.

Total Length in Inches	Caruthersville, Mo. April 6–12, 1944	Tiptonville, Tenn. April 15–May 10	Cairo, Ill. May 18–25	Cape Girardeau, Mo. May 26–31	Grand Tower, Ill. June 2–9	Chester, Ill. June 11–15	Ste. Genevieve, Mo. June 18–24	Crystal City, Mo. June 25–30	Cliff Cave, Mo. July 2–8	Below Mouth of Missouri River July 10–15	Above Mouth of Missouri River July 10–15	Grafton, Ill. March 22–30	Grafton, Ill. July 15–25	Grafton, Ill. Sept. 22–27	Winfield, Mo. July 27–Aug. 2	Hamburg, Ill. Aug. 3–9	Louisiana, Mo. Aug. 12–17	Cincinnati Ldg., Ill. Aug. 19–23	Hannibal, Mo. Aug. 25–30
3.8– 4.7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
4.8– 5.7	—	—	—	—	—	8	3	—	—	—	—	2	—	—	—	—	—	—	—
5.8– 6.7	—	1	—	—	—	13	6	—	—	—	—	—	—	—	1	—	—	—	—
6.8– 7.7	1	1	—	—	3	6	8	—	—	—	—	—	—	—	—	1	—	—	—
7.8– 8.7	4	2	—	—	2	1	3	—	—	—	4	—	—	—	1	—	—	—	—
8.8– 9.7	2	1	3	—	2	4	2	—	—	—	24	2	3	—	1	1	1	—	—
9.8–10.7	1	1	1	—	5	—	2	2	—	—	49	—	3	—	2	—	1	—	3
10.8–11.7	—	4	3	1	6	—	5	—	1	2	34	—	6	—	2	1	1	—	3
11.8–12.7	2	6	5	6	16	6	9	6	2	—	37	4	2	1	14	1	1	1	1
12.8–13.7	2	3	7	1	23	22	53	15	11	4	51	14	7	2	12	7	1	2	12
13.8–14.7	6	7	10	7	38	17	65	26	23	8	43	9	6	2	20	15	5	2	12
14.8–15.7	3	16	10	14	24	16	62	44	44	6	34	9	4	3	11	11	4	13	15
15.8–16.7	10	6	5	13	25	12	52	43	33	10	16	3	4	4	6	6	4	7	8
16.8–17.7	4	2	2	13	7	11	26	37	30	10	7	4	1	1	4	4	5	10	4
17.8–18.7	1	4	4	4	3	10	10	19	17	7	2	2	2	3	2	3	3	2	3
18.8–19.7	1	3	1	5	1	5	5	4	6	5	3	—	3	1	—	3	3	2	1
19.8–20.7	—	3	4	6	1	2	3	7	7	1	2	—	—	—	2	—	1	4	2
20.8–21.7	—	—	4	3	1	1	—	2	2	—	2	—	1	—	—	1	1	—	2
21.8–22.7	—	1	—	3	2	—	—	3	3	—	—	1	2	—	1	—	2	1	1
22.8–23.7	—	1	—	4	1	1	3	1	3	—	—	—	—	1	—	—	—	1	3
23.8–24.7	—	—	1	—	2	2	1	—	1	—	—	1	1	—	—	—	—	—	1
24.8–25.7	—	1	—	2	—	1	1	—	—	—	—	—	—	—	—	—	—	—	1
25.8–26.7	—	—	—	—	—	2	—	1	—	—	1	—	—	—	—	—	—	—	1
26.8–27.7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
27.8–28.7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—
28.8–29.7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
29.8–30.7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2
30.8–31.7	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—
31.8–32.7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
32.8–33.7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Total number	*37*	*63*	*60*	*82*	*162*	*140*	*320*	*210*	*183*	*54*	*309*	*51*	*45*	*18*	*79*	*55*	*33*	*45*	*75*
Average length	14.1	15.0	15.3	17.2	14.5	13.8	14.7	16.2	16.4	16.3	12.9	14.3	14.6	16.3	14.1	15.3	16.3	16.7	16.3
Average weight in pounds	1.62	2.03	2.21	3.01	1.85	1.94	1.93	2.35	2.57	2.48	1.21	1.73	1.79	2.28	1.50	1.79	2.28	2.31	2.38

Table 12.—Concluded.

TOTAL LENGTH IN INCHES	QUINCY, ILL. SEPT. 2–6	CANTON, MO. SEPT. 8–13	WARSAW, ILL. SEPT. 14–19	BURLINGTON, IA. APRIL 10–22, '46	OQUAWKA, ILL. APRIL 24–MAY 5	NEW BOSTON, ILL. MAY 7–18	MUSCATINE, IA. MAY 19–30	FAIRPORT, IA. JUNE 2–13	ANDALUSIA, ILL. APRIL 1–7	ANDALUSIA, ILL. JUNE 18–26	ANDALUSIA, ILL. SEPT. 15–24	PLEASANT VALLEY, IA. JUNE 28–JULY 9	CORDOVA, ILL. JULY 11–22	FULTON, ILL. JULY 24–AUG. 4	SABULA, IA. AUG. 6–17	BELLEVUE, IA. AUG. 19–30	DUBUQUE, IA. SEPT. 1–12	TOTAL OR AVERAGE
3.8– 4.7	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1
4.8– 5.7	1	—	—	8	—	—	—	—	—	—	—	—	—	—	—	—	—	22
5.8– 6.7	—	—	—	6	—	—	—	—	—	—	—	—	1	—	—	—	—	28
6.8– 7.7	—	1	—	3	1	—	—	1	—	—	—	—	—	—	—	—	—	26
7.8– 8.7	—	—	1	2	—	—	2	—	—	—	—	—	—	—	—	—	—	22
8.8– 9.7	2	—	—	—	—	—	—	—	—	—	—	1	1	—	—	—	—	50
9.8–10.7	2	1	5	2	—	—	—	—	—	—	2	1	—	1	—	—	—	84
10.8–11.7	3	2	4	1	—	2	—	—	—	—	4	—	—	1	—	—	—	86
11.8–12.7	3	—	6	—	—	2	—	—	—	—	19	—	1	5	—	—	3	159
12.8–13.7	3	1	11	1	—	—	4	—	—	1	3	—	1	6	—	3	2	285
13.8–14.7	11	3	10	1	—	—	19	9	—	1	5	—	3	10	1	—	3	397
14.8–15.7	23	6	19	—	—	4	11	8	—	4	11	—	—	5	4	3	1	442
15.8–16.7	23	7	19	5	2	10	8	7	1	4	35	3	9	13	5	—	—	418
16.8–17.7	20	5	10	5	—	11	26	8	3	14	73	5	10	10	7	2	5	396
17.8–18.7	18	7	10	6	6	12	36	19	2	18	62	3	11	14	5	11	11	352
18.8–19.7	10	7	5	4	10	14	38	11	2	16	38	4	6	14	2	5	8	246
19.8–20.7	8	6	6	7	5	9	32	9	3	13	24	1	7	14	8	6	6	209
20.8–21.7	1	3	4	6	3	9	16	4	1	9	18	9	10	7	8	3	9	140
21.8–22.7	3	1	2	3	4	7	11	4	1	6	14	5	5	11	4	1	3	106
22.8–23.7	1	1	—	2	1	6	7	—	—	2	9	3	4	8	1	2	3	69
23.8–24.7	2	1	1	5	1	5	5	—	—	—	6	1	3	3	—	—	1	44
24.8–25.7	1	—	—	2	—	—	1	2	—	1	5	1	2	3	2	2	—	28
25.8–26.7	1	—	—	1	—	—	2	—	—	1	2	—	—	5	5	—	2	24
26.8–27.7	1	—	—	1	—	—	—	—	—	—	2	—	2	2	—	2	3	13
27.8–28.7	—	—	1	—	—	—	1	—	—	1	—	—	2	—	—	1	1	8
28.8–29.7	—	—	—	—	—	—	—	1	1	—	—	1	—	—	—	—	—	3
29.8–30.7	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	1	1	5
30.8–31.7	—	—	—	—	—	—	—	—	—	1	—	—	1	—	—	—	2	5
31.8–32.7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1
32.8–33.7	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	1
Total number	*137*	*52*	*114*	*72*	*33*	*91*	*219*	*83*	*14*	*93*	*333*	*38*	*79*	*132*	*52*	*42*	*65*	*3,670*
Average length	16.8	17.4	16.0	15.9	19.5	18.8	18.7	18.1	19.8	19.4	18.2	19.9	19.5	17.8	19.9	20.2	20.4	16.5
Average weight in pounds	2.52	2.68	2.23	3.37	3.85	3.56	3.71	3.17	3.61	3.62	3.35	4.13	4.37	3.54	4.19	4.70	4.96	2.65

Table 13.—Ranges and averages of Indices of Condition (C) of two length-groups of carp in test-net collections from the Mississippi River between Caruthersville, Missouri, and Dubuque, Iowa, in 1944 and 1946.

Station	Carp With Total Length of 14.6 Inches to 15.5 Inches			Carp With Total Length of 16.6 Inches to 17.5 Inches		
	Number	Range of C	Average C	Number	Range of C	Average C
1944						
Caruthersville	3	4.77–5.20	4.96	1	—	6.32
Tiptonville	16	4.32–6.80	5.43	3	4.83–6.30	5.37
Cairo	12	5.13–6.60	5.83	1	—	5.37
Cape Girardeau	9	4.65–5.64	5.22	9	4.68–6.37	5.59
Grand Tower	18	4.56–6.07	5.46	3	4.15–5.36	4.82
Chester	18	5.20–7.11	5.83	13	3.38–6.49	5.15
Ste. Genevieve	55	3.38–6.36	5.51	26	4.63–6.60	5.44
Crystal City	35	4.56–5.78	5.33	15	4.23–6.39	5.36
Cliff Cave	14	4.15–5.98	5.37	24	4.86–6.26	5.39
Mouth Missouri	26	4.81–5.82	5.16	8	4.55–5.63	4.93
Grafton (March)	3	5.12–5.32	5.19	3	4.87–5.42	5.18
Grafton (July)	6	4.60–5.06	4.85	2	4.26–5.04	4.65
Grafton (Sept.)	5	4.54–5.11	4.79	1	—	5.10
Winfield	14	3.24–5.72	4.76	4	4.57–5.56	5.11
Hamburg	14	3.46–5.94	4.65	6	4.11–5.07	4.57
Louisiana	5	4.18–5.17	4.61	5	4.09–4.70	4.47
Cincinnati Landing	10	4.35–5.00	4.63	9	3.51–5.13	4.56
Hannibal	15	4.05–5.07	4.68	2	4.56–5.09	4.82
Quincy	12	2.87–5.56	4.65	23	4.21–5.52	4.93
Canton	6	4.56–5.10	4.81	5	4.44–5.20	4.80
Warsaw	0	—	—	14	4.29–5.92	5.08
1946						
Burlington	0	—	—	6	2.63–5.84	4.87
Oquawka	0	—	—	0	—	—
New Boston	2	4.68–4.89	4.79	8	4.03–6.11	4.99
Muscatine	18	4.74–6.55	5.59	22	4.43–6.38	5.06
Fairport	9	4.63–5.67	5.20	8	4.56–5.54	4.96
Andalusia (April)	0	—	—	2	5.27–5.43	5.35
Andalusia (June)	3	4.95–5.98	5.46	12	4.81–5.68	5.22
Andalusia (Sept.)	7	5.03–5.78	5.30	66	4.27–6.23	5.09
Pleasant Valley	0	—	—	3	4.30–5.54	4.75
Cordova	2	3.83–4.88	4.36	6	4.50–5.93	4.94
Fulton	7	4.72–5.27	4.99	11	4.51–5.52	4.97
Sabula	3	4.35–4.87	4.57	11	4.22–5.32	4.73
Bellevue	2	4.94–5.53	5.24	2	4.57–6.09	5.33
Dubuque	1	—	4.93	2	4.32–5.18	4.75

number of year classes overlapping in length ranges have been discussed by Frey (1942:217). Because of these difficulties, it was necessary to rely on the length-frequency method of aging even though it, too, has limitations and is not well suited for use on carp populations. From the data given in table 12, it appears that the bulk of the carp catch was composed of 2- and 3-year-old fish.

It was determined by examining the gonad condition of carp taken in the survey that sexual maturity was reached in the females at lengths of 14 to 15 inches, in most males at lengths of 12.5 to 14.5 inches. However, some males as small as 8.5 inches were mature. The catches made by test-netting indicate that many carp below these lengths are taken in commercial type gear. The over-all average length of carp taken in both years of the survey was 16.5 inches, a figure a little over the minimum maturity length.

The Index of Condition (C)* is often used as an indicator of the relative plumpness of a fish. In table 13 the ranges and averages of Indices of Condition are given for two length groups of carp. At many

* The formula $C = \frac{W\ 10{,}000}{L^3}$ suggested by Thompson & Bennett (1939:17) was used in computing the Index of Condition.

stations too few specimens of the selected length groups were taken to permit direct comparison; however, where 10 or more specimens were taken it seemed justifiable to make comparisons. The Index of Condition, or C, ranged from 2.63 to 7.11. Carp having a C below 3.50 gave an outward appearance of being in poor condition and most of them were emaciated. Inspection of table 13 indicates that the average C is a little less than 5.00. Most of the carp taken in the spring and early summer (in the MR-C section) had a C above this value; most of those taken later in the season of the same year (in the D-MR section) had a C below 5.00. A similar seasonal difference was noted also at the two key stations. The upper C range at the key stations, as well as at the majority of the other stations, was above 5.00. The average C of carp taken in the polluted waters below St. Louis was much higher than that for carp taken above St. Louis. This difference may be attributed partly or entirely to seasonal changes. In the section of this paper on "Pollution" mention is made that the carp on the Illinois side of the Mississippi near Warsaw appeared very fat; their condition was attributed to their feeding upon brewery waste. It is of interest to note in table 13 that the average Index of Condition was higher at Warsaw than at the preceding stations below it sampled in late summer.

Catfishes and Bullheads

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The catfishes are considered by many to be the finest-tasting fresh-water fishes in North America. Their white, firm flesh has long made them leaders in demand at midwestern river commercial fish markets. Commercial fishermen frequently are unable to meet the local public demand for these food fishes. The catfishes are popular with anglers, also. It is often said that an angler who has never tried fishing with a light rod for the channel catfish (*Ictalurus lacustris*) has "just never

Fig. 10.—A Mississippi River commercial fisherman dressing a catfish. An experienced fisherman can dress a catfish in less than a minute.

Fig. 11.—Raising a small-mesh hoop net on the Mississippi River. The small-mesh nets are particularly effective for catfish.

fished." The flathead catfish (*Pilodictis olivaris*) and the blue catfish (*Ictalurus furcatus*) are regularly taken by anglers either by trotline fishing or by jug fishing.

In the Mississippi the three species of catfishes mentioned above form an important part of the commercial catch, figs. 10, 11, and 12. The species of catfishes and bullheads, like the species of buffalofishes, are usually lumped together in commercial fisheries statistics. The commercial catch of Mississippi River catfishes and bullheads reported for Illinois and Iowa in 1946 amounted to a little more than 50 per cent of the comparable catch reported in 1899, table 7. This table shows the

Fig. 12.—Removing catfish from a basket trap. In the spring commercial fishermen often "bait" this type of trap with a ripe female catfish.

large decline that occurred in the commercial take of these fishes between 1894 and 1899. The Illinois catch of catfishes and bullheads from the Mississippi, table 9, amounted to 20.3 per cent of the weight of the total commercial catch in 1894 and 15.1 per cent of that catch in 1946. These figures are hardly comparable in view of the change in abundance of other commercial fishes. At Lake Keokuk the largest commercial catch of catfishes and bullheads since 1914 was taken in 1936, table 8. This table indicates that in 1936 a large increase in catch occurred on the Illinois side of the Mississippi from Lake Keokuk to the northern boundary of the state. The following year the catch in that part of the river was reduced by almost one-half.

The test-net data obtained between Caruthersville and Dubuque reveal that the relative abundance of the catfish species is not constant in the three sections of the Mississippi indicated in fig. 13. By weight, the flathead was the most important catfish in all three sections, fig. 13. Numerically, the flathead was the most important catfish in the MR-C section and the channel catfish the most important in the other two sections. The blue catfish was more abundant in the MR-C section than in the D-MR section. No specimen of this species was taken in test nets above Warsaw. About 20 years ago Coker (1930:175) noted that Keokuk, which is 4 miles above Warsaw, was about the northern limit of the summer range of the blue catfish.

The channel catfish was reported by Forbes & Richardson (1920:181) as occasionally attaining a weight of 15 to 20 pounds. The largest specimen of this species observed during the 2 years of this investigation was taken at Burlington; it weighed 13.06 pounds. The average weight of the channel catfish in the test-net catches was 0.45 pound, Appendix B.

The flathead catfish was reported by Forbes & Richardson (1920:194) as frequently reaching a weight of 50 to 75 pounds and by Evermann (1899:293) as attaining a weight of 50 to 60 pounds and, rarely, 100 pounds. At Cincinnati Landing a flathead catfish weighing 42.56 pounds was taken by the 1944 survey party in a wing net. The average weight of the flathead in the test-net collections was 3.08 pounds, Appendix B.

The average weight of the blue catfish in the test-net collections was surprisingly

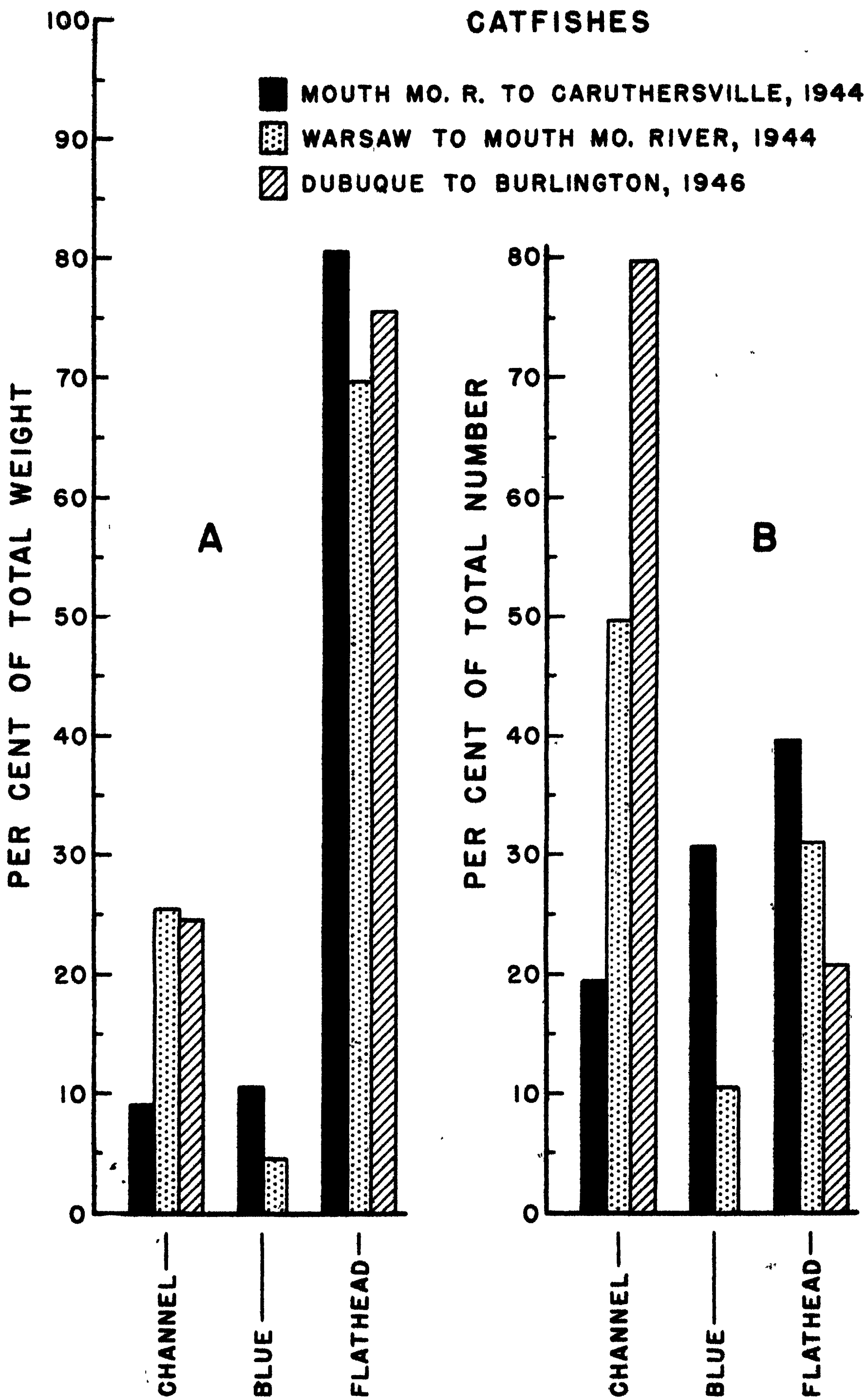

Fig. 13.—The relative weight and the relative abundance of each of three species of catfishes taken in test-net collections from three sections of the Mississippi River, 1944 and 1946.

low, only 0.57 pound, Appendix B, table 1. This species is principally southern in distribution and evidently forms a substantial part of the catch in the lower part of the Mississippi, particularly in Louisiana. Evermann (1899:292) stated more than 50 years ago that at Morgan City and Melville, Louisiana, the blue catfish and the flathead catfish constituted probably 98 per cent of the entire catch. Later Gowanloch (1933:421) mentioned that blue catfish weighing 150 pounds were caught occasionally and quoted Evermann as having been informed of one specimen weighing 185 pounds and another 250 pounds. Reports by commercial fishermen of 75- and 90-pound blue catfish were not uncommon in the section of the river near Caruthersville. No catfish of these large sizes were taken in the test nets.

Age determinations of the channel catfish and flathead catfish were made from specimens collected during the survey; they were based on the number of rings or annuli on the vertebrae. The number of annuli on the vertebrae of the blue catfish could not be discerned with any degree of accuracy. From the growth studies it appears that channel catfish and flathead catfish do not mature until they are 4 or 5 years old. The size at which they attain maturity was found to vary considerably. A few mature female flathead catfish less than 15 inches total length were noted; however, the majority of mature females were 18 inches or more in length. The channel catfish was found to mature at lengths between 12 and 15 inches. Too few blue catfish were examined to determine maturity size for this species.

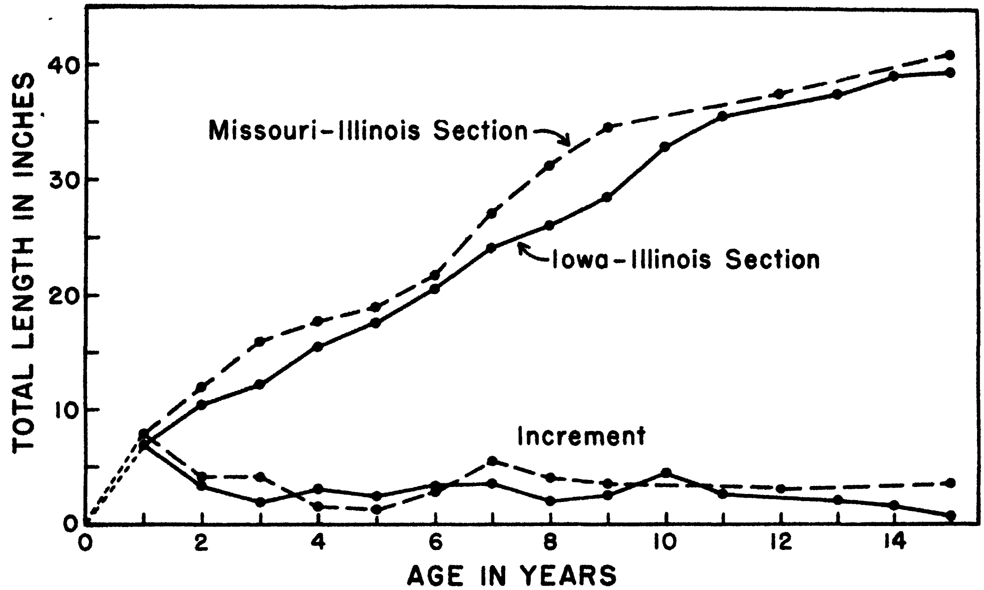

Fig. 14.—Average growth rates of flathead catfish taken in the Missouri-Illinois and Iowa-Illinois sections of the Mississippi River as determined from test-net collections, 1944 and 1946.

Growth of the channel catfish and flathead catfish was faster in the Missouri-Illinois section of the river than in the Iowa-Illinois section, fig. 14.

The length-frequency distribution of the catfishes from the test-netting collections is given in table 14. A line of demarcation is drawn on table 14 to set off the approximate size at which maturity is attained among the catfishes. The 15-inch set-off for the blue catfish is purely arbitrary.

Three species of bullheads were taken from the river during the 2 years of test-netting. As shown in table 15, the black bullhead (*Ameiurus melas*) made up 5.6 per cent of the total number of all fishes taken in the MR-C section in 1944. In that part of the D-MR section sampled that same year the black bullhead dropped

to an insignificant 0.6 per cent and in that part sampled in 1946 to 0.5 per cent. Black bullheads were taken in numbers at only four of the stations in the MR-C section, Appendix B, table 1. The black bullheads taken at these stations represented 82 per cent of the number of this species caught in 1944 and 68 per cent of all the black bullheads taken in the entire survey. At the six stations immediately below the canalized section of the river (stations south of Grafton) only five black bullheads were caught, numerically 1.6 per cent of the 1944 catch of black bullheads.

Table 14.—Length-frequency distribution of the catfishes in test-net collections from the Mississippi River between Caruthersville, Missouri, and Dubuque, Iowa, in 1944 and 1946. The horizontal broken rule marks the approximate dividing line between immature and mature fish; the line for the blue catfish is based on little evidence and is therefore questionable.

Total Length in Inches	Channel Catfish			Flathead Catfish			Blue Catfish	
	MR-C Section 1944	D-MR Section 1944	D-MR Section 1946*	MR-C Section 1944	D-MR Section 1944	D-MR Section 1946*	MR-C Section 1944	D-MR Section 1944
2.8– 3.7	—	1	6	—	—	—	—	—
3.8– 4.7	—	—	3	—	—	1	—	1
4.8– 5.7	—	1	2	—	—	2	—	—
5.8– 6.7	—	4	99	—	—	2	7	—
6.8– 7.7	4	14	221	—	3	12	15	4
7.8– 8.7	24	14	228	5	6	3	22	17
8.8– 9.7	34	20	210	5	2	11	30	19
9.8–10.7	15	29	111	7	7	11	40	5
10.8–11.7	11	42	69	9	8	17	41	6
11.8–12.7	5	60	34	13	13	20	23	4
12.8–13.7	4	32	27	18	19	20	13	4
13.8–14.7	8	23	32	22	15	17	9	10
14.8–15.7	11	26	33	35	29	22	13	5
15.8–16.7	4	15	18	42	28	22	4	—
16.8–17.7	11	14	10	46	28	26	6	2
17.8–18.7	3	7	12	42	24	18	1	2
18.8–19.7	6	8	2	34	17	5	3	—
19.8–20.7	1	4	7	17	12	11	2	—
20.8–21.7	1	2	1	17	5	12	—	—
21.8–22.7	2	1	2	12	6	3	—	1
22.8–23.7	1	1	2	11	2	7	1	—
23.8–24.7	3	—	3	8	1	3	—	—
24.8–25.7	—	—	1	7	4	11	—	—
25.8–26.7	—	1	—	5	7	7	—	—
26.8–27.7	—	—	—	5	1	4	—	—
27.8–28.7	—	—	1	2	1	5	—	—
28.8–29.7	—	—	—	2	1	1	—	—
29.8–30.7	—	1	1	3	—	1	—	—
30.8–31.7	—	—	1	1	1	1	—	—
31.8–32.7	—	—	—	—	1	5	1	—
32.8–33.7	—	—	—	—	1	2	—	—
33.8–34.7	—	—	—	—	—	1	—	—
34.8–35.7	—	—	—	1	1	2	—	—
35.8–36.7	—	—	—	2	—	2	—	—
36.8–37.7	—	—	—	1	1	5	—	—
37.8–38.7	—	—	—	—	—	1	—	—
38.8–39.7	—	—	—	—	—	2	—	—
39.8–40.7	—	—	—	—	—	—	—	—
40.8–41.7	—	—	—	—	1	—	—	—
Total number	*148*	*320*	*1,136*	*372*	*245*	*295*	*231*	*80*
Average length	12.3	12.8	9.6	17.9	17.0	17.5	11.3	11.0
Per cent mature length	29.1	25.0	8.3	45.7	35.5	36.9	13.4	12.5

* The 1946 D-MR data include 24 channel catfish and 2 flathead catfish caught near Burlington, Iowa, by J. O. Kurrle, a commercial fisherman.

Table 15.—Species composition of Mississippi River fishes taken above and below the mouth of the Missouri River between Caruthersville, Missouri, and Dubuque, Iowa, 1944 and 1946.

SPECIES	MOUTH OF MISSOURI RIVER TO CARUTHERSVILLE, 1944			WARSAW TO MOUTH OF MISSOURI RIVER, 1944			DUBUQUE TO BURLINGTON (ABOVE MOUTH OF MISSOURI RIVER), 1946		
	Per Cent of Total Stations (10) at Which Listed Species Were Taken	Number of Specimens	Per Cent of Total Number of All Fish	Per Cent of Total Stations (12) at Which Listed Species Were Taken	Number of Specimens	Per Cent of Total Number of All Fish	Per Cent of Total Stations (14) at Which Listed Species Were Taken	Number of Specimens	Per Cent of Total Number of All Fish
COMMERCIAL FISHES									
Scaphirhynchus album	—	0	—	8	1	0.01	—	0	—
Shovelnose sturgeon	—	0	—	8	3	0.03	29	281	2.24
Paddlefish	40	24	0.51	42	52	0.59	—	0	—
American eel	30	10	0.21	75	27	0.31	79	17	0.14
Blue sucker	—	0	—	17	3	0.03	21	5	0.04
Bigmouth buffalo	70	48	1.02	92	61	0.69	100	277	2.21
Black buffalo	60	30	0.64	83	28	0.32	86	29	0.23
Smallmouth buffalo	80	127	2.69	100	341	3.88	93	486	3.88
Carpiodes spp.	100	334	7.08	100	605	6.88	100	1,491	11.90
White sucker	—	0	—	—	0	—	21	6	0.05
Spotted sucker	—	0	—	—	0	—	14	2	0.02
Silver redhorse	—	0	—	—	0	—	7	1	0.01
Northern redhorse	10	7	0.15	58	13*	0.15	93	104	0.83
Carp	100	1,311	27.80	100	1,014	11.53	100	1,347	10.76
Channel catfish	100	148	3.14	100	320	3.64	100	1,115	8.90
Blue catfish	100	231	4.90	100	80	0.91	—	0	—
Yellow bullhead	20	4	0.08	50	24	0.27	29	10	0.08
Brown bullhead	10	1	0.02	17	5	0.06	—	0	—
Black bullhead	70	262	5.56	50	48	0.55	79	65	0.52
Flathead catfish	100	372	7.89	92	245	2.78	100	294	2.35
Freshwater drum	100	348	7.38	100	768	8.73	100	1,088	8.69
Subtotal		*3,257*	*69.08*		*3,638*	*41.35*		*6,618*	*52.85*
SPORT FISHES									
Pike	—	0	—	—	0	—	36	35	0.28
Grass pickerel	—	0	—	8	2	0.02	—	0	—
Yellow pikeperch	—	0	—	17	2	0.02	57	17	0.14
Sauger	60	21	0.45	75	46	0.52	71	68	0.54
Spotted black bass	10	2	0.04	—	0	—	7	2	0.02
Largemouth black bass	50	10	0.21	58	123	1.40	64	18	0.14
Green sunfish	20	18	0.38	—	0	—	21	3	0.02
Bluegill	70	39	0.83	67	556	6.32	86	308	2.46
Warmouth	30	15	0.32	25	52	0.59	36	10	0.08
Flier	10	1	0.02	—	0	—	—	0	—
White crappie	70	119	2.52	100	879	9.99	100	2,677	21.38
Black crappie	70	123	2.61	100	1,392	15.82	100	1,452	11.60
White bass	50	24	0.51	83	193	2.19	93	162	1.29
Yellow bass	20	2	0.04	33	4	0.05	57	258	2.06
Subtotal		*374*	*7.93*		*3,249*	*36.93*		*5,010*	*40.00*
PREDATORY FISHES									
Longnose gar	90	51	1.08	100	143	1.63	93	38	0.30
Shortnose gar	100	602	12.77	100	809	9.20	100	209	1.67
Alligator gar	40	84	1.78	8	1	0.01	—	0	—
Bowfin	50	29	0.62	67	81	0.92	93	154	1.23
Subtotal		*766*	*16.25*		*1,034*	*11.75*		*401*	*3.20*
FORAGE FISHES									
Mooneye†	70	43	0.91	92	66	0.75	79	174	1.39
Goldeye†	—	—	—	—	—	—	64	84	0.67
Skipjack	30	11	0.23	17	4	0.05	—	0	—
Gizzard shad	70	264	5.60	100	805	9.15	86	237	1.89
Golden shiner	—	0	—	8	2	0.02	—	0	—
Subtotal		*318*	*6.74*		*877*	*9.97*		*495*	*3.95*
Total		*4,715*	*100.00*		*8,798*	*100.00*		*12,524*	*100.00*

* Includes one specimen of an undetermined species of redhorse (*Moxostoma*).
† The goldeye is included with the mooneye in the 1944 collections.

In July, 1944, at the Grafton station, 14 specimens of black bullheads were taken, Appendix B, table 1. As mentioned in Appendix A, some of the sampling done at this station was in the lower part of the Illinois River and adjoining bottomland lakes, and the catch there may not have been typical of the fish population in the Mississippi. At the next station above Grafton on the Mississippi, five black bullheads were taken, and at the next four stations none was caught. In the aggregate only four specimens were taken at the remaining three uppermost stations used in 1944. The number of black bullheads was low throughout that part of the D-MR section investigated in 1946. The largest number caught at one station in 1946 was 16, at Andalusia in June. The data for the various stations are contained in Appendix B.

The yellow bullhead (*Ameiurus natalis*) was taken at less than half of the stations and was plentiful at none, Appendix B. More specimens were taken at the upper than at the lower stations; however, considerably more than half of the yellow bullheads taken in the survey were caught at the Grafton station, and, as suggested above, the sampling there was not confined to the Mississippi.

Only six brown bullheads (*Ameiurus nebulosus*) were taken in 1944 and none in 1946, Appendix B. Of these only one was taken in the lower river and the remainder were caught at the Grafton station.

The scarcity of bullheads in the D-MR section of the river is reflected by the Iowa commercial catch between 1944 and 1948, table 16. For a few years following canalization of the upper Mississippi the commercial catch of bullheads increased, and it did not show a severe decline until 1944–45. The reason for the decline is not known. The test-net catch of bullheads in 1944 was low at the six sampling stations below the canalized section of the river. According to E. B. Speaker of the Iowa Conservation Commission (letter, August 19, 1949) there again is apparently some increase in the bullhead population in the Iowa section of the Mississippi.

Since so few bullheads were taken in 1946, the length-frequency data of only the 1944 catch are included in table 17. In Illinois the present minimum legal length for bullheads is 9 inches. Age determinations made from vertebrae of the Mississippi River bullheads taken in 1944 tend to indicate that the majority of the black bullheads did not reach the maturity length of approximately 10 inches before the age of 3 years. The yellow bullheads, however, seem to have a more rapid growth rate and attained this length within 2 years. In the 1944 test-net samples, 70 per cent of the black bullheads were 10 inches or more in length. Of the 28 specimens of yellow bullheads taken, 82

Table 16.—Commercial catch of bullheads from the Iowa section of the Mississippi River, 1938–1948.*

YEAR	POUNDS CAUGHT
1938–39	74,246
1939–40	98,577
1940–41	189,129
1941–42	215,675
1942–43	203,040
1943–44	138,385
1944–45	52,158
1945–46	7,679
1946–47	15,618
1947–48	20,306

* Data furnished by E. B. Speaker, Superintendent of Biology Section, Iowa Conservation Commission.

Table 17.—Length-frequency distribution of bullheads in test-net collections from the Mississippi River between Caruthersville, Missouri, and Warsaw, Illinois, in 1944. The horizontal broken rule marks the approximate dividing line between immature and mature fish.

TOTAL LENGTH IN INCHES	BLACK BULL-HEAD	YELLOW BULL-HEAD	BROWN BULL-HEAD
5 8- 6.7	4	—	—
6 8- 7 7	9	1	—
7 8- 8 7	28	2	1
8 8- 9 7	52	2	—
9.8–10 7	98	13	2
10.8–11 7	68	6	—
11.8–12 7	35	3	1
12 8–13 7	11	1	1
13.8–14 7	3	—	1
14.8–15.7	1	—	-
15.8–16 7	1	—	—
Total number	*310*	*28*	*6*
Average length	10 4	10.5	11.4

per cent equaled or exceeded 10 inches in length.

The catfish and bullhead fishery between Caruthersville and Dubuque as demonstrated by the 2 years of test netting is largely a channel cat–flathead fishery. The only other important species of this group, the black bullhead and the blue catfish, are more numerous in the MR-C section than above. The great abundance of the channel catfish in the upper river perhaps compensates somewhat for the small numbers of bullheads in that section and the scarcity of the blue catfish in the river above Warsaw. Yellow bullheads and brown bullheads are too scarce in the river to be of any commercial importance.

Freshwater Drum

SCIAENIDAE

In the Midwest commercial market the freshwater drum is usually called white perch. In the Mississippi River this fish is of great importance commercially and of some value as a sport fish. According to Forbes & Richardson (1920:324), weights of 50 to 60 pounds were in their time not uncommon for this fish. In the opinion of these writers the freshwater drum "becomes tough and strong with age, but is at its best when weighing from three-quarters of a pound to three pounds. . . . This fish is of a sluggish habit, living on the bottom of muddy waters, where it feeds especially on mollusks, the shells first being crushed by the powerful, paved, millstone-like, pharyngeal jaws. Often the stomach contains only the soft bodies and opercula of gastropod mollusks, the crushed shells evidently having been thrown out. Crawfishes are also sometimes found in the food. Half-grown specimens feed largely on aquatic insects, especially the larvae of May-flies, mingling larger and larger proportions of mollusks with this food as they increase in size, until they come finally to depend almost wholly upon water-snails and the relatively thin-shelled clams."

Although the increased silt load and canalization have modified the Mississippi as an invertebrate habitat, the freshwater drum has evidently been able to withstand the changes and is still one of the most abundant fishes in the river. In the test-netting study the freshwater drum was found to be abundant at all the sampling stations between Caruthersville and Dubuque.

In 1946 the freshwater drum ranked fourth in weight of catch among Mississippi River fish groups reported by commercial fishermen of Illinois, Iowa, and Missouri, table 7. It ranked second among species in the test-net survey, as the buffalofish, carpsucker, catfish, and bullhead groups were each composed of more than one species. Its relative abundance in the three sections of the river indicated in table 15 did not vary appreciably.

The average weight of the freshwater drum in the survey catches was 0.67 pound, Appendix B. As shown in table 18 the average length for individuals of this species varied somewhat in the three sections indicated. Many more large individuals, that is, fish 14 inches or more in length, were taken in 1946 than in 1944.

Table 18.—Length-frequency distribution of the freshwater drum in test-net collections from the Mississippi River between Caruthersville, Missouri, and Dubuque, Iowa, in 1944 and 1946. The horizontal broken rule marks the approximate dividing line between immature and mature fish.

Total Length in Inches	MR-C Section 1944	D-MR Section 1944	D-MR Section 1946*
3.8– 4.7	—	12	25
4.8– 5.7	4	36	121
5.8– 6.7	28	44	59
6.8– 7.7	34	117	80
7.8– 8.7	24	99	122
8.8– 9.7	36	82	129
9.8–10.7	43	80	70
10.8–11.7	39	69	70
11.8–12.7	58	99	77
12.8–13.7	51	81	92
13.8–14.7	11	40	125
14.8–15.7	10	10	86
15.8–16.7	—	4	54
16.8–17.7	—	4	20
17.8–18.7	1	—	7
18.8–19.7	—	—	7
21.8–22.7	—	—	1
Total number	*339*	*777*	*1,145*
Average length	10.5	9.9	10.6
Per cent mature fish	6.5	7.5	26.2

* The 1946 D-MR data include 58 specimens caught near Burlington, Iowa, by J. O. Kurrle, a commercial fisherman.

Studies made on the scales of the freshwater drum from the Mississippi indicate that, on the average, the drum does not attain a length of 14 inches until it is 5 years of age in the Illinois-Missouri section and 6 years of age in the Illinois-Iowa section. The minimum legal length limit of 10 inches, which has been in effect for some time in the state of Illinois, appears to have allowed a favorable take without seriously depleting the population.

The length at which the freshwater drum matures was found to be variable. A female 10.5 inches in length was found spent, and individuals of 15.0 and 15.5 inches were determined as immature or developing. Probably length variation within a group is associated with the age of that group, since a wide length range for each age group was common.

In 1946 the freshwater drum commanded a price along the Mississippi about equal to that of the buffalofishes, approximately 10 cents a pound, undressed weight. In that year, undressed carp brought about 5 cents a pound and undressed catfish approximately 20 cents a pound.

SPORT FISHES

The sport fishery of the Mississippi River between Caruthersville and Dubuque is confined largely to the D-MR section. There sport fishing is, for the most part, conducted in the pools immediately below the dams and in backwaters and bottomland lakes adjoining the river.

Bluegills (*Lepomis macrochirus*) and crappies were by far the most abundant species of sport fishes in the test-net collections. Black basses, pike, sauger, and yellow pikeperch (walleye) were taken in only limited numbers. Experience has demonstrated that the black basses are not so susceptible to being caught in nets and seines as are most of the other fishes. This possibly explains the scarcity of black basses in many of the collections.

Fig. 9 portrays the abundance of sport fishes in the collections from test-net stations in the Caruthersville-Dubuque section of the river. In this figure it may be clearly seen that the sport fishes made up a smaller part of the total catch in the MR-C section of the river than in the

Table 19.—Relative abundance of individuals of the several groupings of Mississippi River fishes associated with upper, middle, and lower reaches of navigation pools between Burlington and Dubuque, Iowa, in 1946, expressed as per cents of total numbers and total weights of fishes.

Location in Pool and Station	Commercial		Sport		Predator		Forage		Total	
	Per Cent of Total Number	Per Cent of Total Weight	Per Cent of Total Number	Per Cent of Total Weight	Per Cent of Total Number	Per Cent of Total Weight	Per Cent of Total Number	Per Cent of Total Weight	Number of Fish	Pounds
Upper Part (New Boston, Ill., Pleasant Valley, Ia., Fulton, Ill., Dubuque, Ia.)	35.91	67.25	57.56	23 03	3.14	8 55	3 39	1 17	4,715	4,256.36
Middle Part (Burlington, Ia., Oquawka, Ill., Muscatine, Ia., Andalusia, Ill., Cordova, Ill., and Sabula, Ia.)	67.57	89.19	28.45	5.48	2.95	5.08	1.02	0.25	6,537	7,935 97
Lower Part (Fairport, Ia., and Bellevue, Ia.)	60 22	88 96	34 28	5.69	4 72	5.32	0 79	0.03	1,272	1.625.16

D-MR section. Because of the scarcity of adjoining backwaters and bottomland lakes, together with a high degree of turbidity in the channel, the MR-C section is visibly less satisfactory as a habitat for most of the sport fishes than the D-MR section. A much more favorable habitat for these fishes is provided by the D-MR section; however, the increased silt load of the river, silting above the dams, and the draining of adjoining bottomland lakes have contributed toward reducing the potentialities of this section of the river for sport fishes.

Netting operations in the various parts of the pools formed by the dams in the D-MR section revealed that the game fishes were most abundant in the upper reaches. The catches of all fishes in the upper, middle, and lower reaches of the pools are summarized in tables 19 and 20. A relative increase in the catch of commercial fishes occurred in the middle and lower reaches as the intensity of fishing was increased there, although the total catch (all species combined) per net-day actually dropped. The relative increase in the catch of commercial fishes as reflected by table 19 is due partly to the scarcity of sport fishes in catches from the middle and lower reaches. The upper reaches of the pools provide a more favorable habitat for sport fishes than the middle and lower reaches in that the bottoms in the upper reaches are comparatively free of silt. Here probably more food is available in the form of aquatic insects and minnows than over the silt-covered bottoms in the middle and lower reaches of the pools. Deep holes and shallow sand bars are rather numerous in the upper reaches of the pools, and this type of habitat is usually considered favorable for sport fishes.

Early in this century, and before, sport fishes were taken commercially from the Mississippi. During the year 1899, Townsend (1902:681) reports, 18,744 pounds of "black bass" were caught commercially by Illinois fishermen from the Mississippi and 102,579 pounds from the Illinois

Table 20.—The 1946 hoop-net and wing-net catches expressed in average numbers and weight of fish per net-day in relation to location in navigation pools of the Mississippi River between Burlington and Dubuque, Iowa.

Location in Pool and Station	1-Inch Mesh Wing Net		2½-Inch Mesh Wing Net		1-Inch Mesh Hoop Net		2½-Inch Mesh Hoop Net	
	Average Number of Fish per Net-Day	Average Weight of Fish per Net-Day	Average Number of Fish per Net-Day	Average Weight of Fish per Net-Day	Average Number of Fish per Net-Day	Average Weight of Fish per Net-Day	Average Number of Fish per Net-Day	Average Weight of Fish per Net-Day
Upper								
New Boston	17.66	10.09	1.68	5.07	4.12	1.13	0.98	3.01
Pleasant Valley	7.71	7.15	1.24	4.22	1.14	0.84	1.04	4.38
Fulton	24.91	12.59	1.33	3.55	6.05	7.73	2.30	6.60
Dubuque	10.16	5.97	0.91	3.68	2.22	0.70	0.59	2.42
Average for upper part	*15.11*	*8.95*	*1.29*	*4.13*	*3.38*	*2.60*	*1.23*	*4.10*
Middle								
Burlington	13.92	6.32	1.50	5.29	4.21	2.10	1.13	2.64
Oquawka	7.58	5.05	1.58	4.58	0.73	1.89	1.32	2.92
Muscatine	6.56	3.09	0.81	2.05	0.75	0.28	2.16	4.75
Sabula	11.01	5.04	0.51	1.39	1.76	2.39	0.47	2.91
Andalusia (April)	6.99	4.43	1.44	4.50	1.18	0.40	0.15	0.30
Andalusia (June)	9.02	9.16	2.76	7.37	5.33	6.87	4.45	8.53
Andalusia (Sept.)	6.32	3.14	0.88	2.65	1.70	2.72	0.51	1.55
Cordova	7.48	5.40	0.79	2.45	4.49	2.16	0.57	3.12
Average for middle part	*8.61*	*5.20*	*1.28*	*3.79*	*2.52*	*2.35*	*1.35*	*3.34*
Lower								
Fairport	5.51	5.54	1.71	3.89	0.11	0.02	0.55	2.52
Bellevue	6.76	3.77	0.43	1.47	0.80	1.18	0.47	2.49
Average for lower part	*6.13*	*4.66*	*1.07*	*2.68*	*0.46*	*0.60*	*0.51*	*2.51*

River; 33,641 pounds of "sunfish" were taken from the Mississippi and 507,680 pounds from the Illinois. These statistics indicate that the section of the Mississippi bordering Illinois was not then a great producer of sport fishes, at least when compared with the Illinois River.

Pike and Pickerel

ESOCIDAE

Pike are often referred to by Midwest fishermen as pickerel. In the Mississippi River a species of pickerel, as well as the pike (*Esox lucius*), was taken in the test nets. The grass pickerel (*Esox vermiculatus*) seldom attains a length over 15 inches. This little pickerel was taken in the test-net collections only at the Grafton station and it is of no importance as either a commercial or sport fish.

Pike, popularly known as northern pike, did not appear in the test-net collections below the station at New Boston, where a single specimen weighing 3.49 pounds was taken. The absence of pike in the collections below this station substantiates the statement of Coker (1930:214) that Keokuk, which is 69 miles below New Boston, "is evidently south of the common range of the true pike in the Mississippi River." More than 91 per cent of the pike taken during the entire survey were caught at the four uppermost 1946 sampling stations.

Commercial fishery statistics suggest that the pike has not been common in the Missouri section of the Mississippi River for at least a half century. In 1894 pike represented 0.01 per cent of the total Missouri commercial catch from the Mississippi, and no pike was reported for the year 1899, table 8. In the Illinois section of the Mississippi, the pike was rather common in the commercial catch for 1894 and 1899. In the Iowa section, the catch of pike by commercial fishermen amounted to 25,042 pounds in 1899. Forbes & Richardson (1920:209), writing nearly a half century ago, stated that the number of pike had greatly decreased in Illinois waters during the previous 25 years.

The taking of pike is now restricted in the Caruthersville-Dubuque section of the river to sport fishing, and the species is too scarce in this section, other than in the upper part, to be of much importance even as a sport fish.

Perches

PERCIDAE

Three species of sport fishes belonging to the perch family have been reported to occur in the Mississippi River. The yellow perch, *Perca flavescens* (Mitchill), according to Forbes & Richardson (1920:227), is essentially a lake fish but occurs also in running water, most abundantly in the larger rivers. Townsend (1902:684, 721) gave the 1899 commercial take of the yellow perch from the Mississippi River by Illinois fishermen as 1,521 pounds and by Iowa fishermen as 9,665 pounds. He did not report a yield of perch for the Missouri section of the river. Coker (1930:204) wrote several years later that the yellow perch was apparently not common in the vicinity of Keokuk, but suggested that it might become more abundant in the impoundment at Keokuk since it is "essentially a lake fish." He reported that the expected increase had not occurred up to 1926.

In the Caruthersville-Dubuque survey not a single specimen of yellow perch was taken. This fish is usually not considered "net shy" and it appears that if the species occurred in numbers in the parts of the river investigated at least a few specimens would have been netted. Although the yellow perch formerly occurred abundantly enough in the Iowa section of the Mississippi to be of some value commercially, the draining of bottomland lakes and backwaters in the valley may have had the effect of reducing the population. These former lakes probably abounded in aquatic vegetation and, according to Greene (1935:162), one of the most potent ecological factors in the distribution of the yellow perch is aquatic vegetation, a usual necessity for successful spawning. Large perch populations frequently are associated with extensive sandy shoals, and silting of such areas may limit the numbers of perch.

The pikeperches are of some importance to the sport fishery of the Mississippi River, and large catches of these fishes are not uncommon from the upper part of the D-MR section of the river. Experienced anglers usually make their catches in the fall. In

Table 21.—Length-frequency distribution of the sauger and the yellow pikeperch in test-net collections from the Mississippi River between Caruthersville, Missouri, and Dubuque, Iowa, in 1944 and 1946.

Total Length in Inches	Sauger			Yellow Pikeperch	
	MR-C Section 1944	D-MR Section 1944	D-MR Section 1946	D-MR Section 1944	D-MR Section 1946
8.8- 9.7	—	—	4	—	3
9.8-10.7	—	—	1	—	2
10.8-11.7	2	1	9	—	—
11.8-12.7	5	1	9	—	5
12.8-13.7	9	10	13	—	1
13.8-14.7	4	7	17	—	1
14.8-15.7	1	13	11	1	—
15.8-16.7	—	14	4	—	1
16.8-17.7	—	—	—	—	—
17.8-18.7	—	—	—	—	1
18.8-19.7	—	—	—	—	—
19.8-20.7	—	—	—	—	—
20.8-21.7	—	—	—	—	—
21.8-22.7	—	—	—	1	—
22.8-23.7	—	—	—	—	2
23.8-24.7	—	—	—	—	—
24.8-25.7	—	—	—	—	1
Total number	*21*	*46*	*68*	*2*	*17*
Average length	13.1	14.8	13.3	18.8	14.3

those sections of the Mississippi surveyed, two species of pikeperches were taken, namely, sauger (*Stizostedion canadense*) and yellow pikeperch, known also as walleye (*S. vitreum vitreum*). The sauger was much more abundant in the Caruthersville-Dubuque section of the river than the yellow pikeperch. In the Caruthersville-Warsaw section 67 specimens of sauger were taken as compared with only 2 specimens of yellow pikeperch. The yellow pikeperch did not occur in any of the collections from the MR-C section. In the Burlington-Dubuque section the sauger continued to be more abundant than the yellow pikeperch. From this section of the river 68 saugers and 17 yellow pikeperches were taken. According to Coker (1930:204), the sauger was evidently much more common than the yellow pikeperch at Keokuk 20 or more years ago. On the basis of the distribution and abundance of the pikeperches it appears that the sauger is much more tolerant of turbid waters than the yellow pikeperch.

Table 21 indicates that the sauger is usually smaller than the yellow pikeperch. The largest yellow pikeperch taken during the survey was 24.9 inches in length and weighed 6.25 pounds.

Black Basses and Other Sunfishes

Centrarchidae

The black crappie (*Pomoxis nigromaculatus*) and the white crappie (*Pomoxis annularis*) were the most abundant sunfishes taken in the survey. Crappies were taken at all but three of the stations; however, they were much more common in the D-MR section than in the section below, Appendix B. In the MR-C section crappies accounted for only 5.1 per cent of the total number of all fishes caught in test nets, whereas in the lower D-MR section, that part surveyed in 1944, crappies represented 25.8 per cent of the total test-net catch. In the Burlington-Dubuque section, surveyed in 1946, crappies accounted for 33.0 per cent of all fishes in the test-net collections. The abundance of the crappies relative to the other species of sport fishes is expressed graphically in fig. 15. It may be seen from this graph that at the majority of the stations crappies were more abundant in the collections than all the other sport fishes combined. At the stations where other sport fishes predominated, there were only small total catches of sport fishes. Usually at such stations the sauger and white bass domi-

nated the sport fish catch. In the MR-C collections the black crappie appeared to be slightly more abundant than the white. In the 1944 D-MR collections, the black crappie was almost twice as abundant as the white; however, the dominant black crappie populations were confined to the station just above the mouth of the Missouri River, the next station upstream, which is Grafton, and Cincinnati Landing. At the last of these stations only 7 crappies were taken, a number too small to be of any significance. At Grafton the black crappie was extremely abundant as compared with the white. At Winfield, the next station upstream from Grafton, the crappie population was predominantly white. This dominance of white crappies continued at the remaining upper river stations in 1944 and 1946 with the exception of Cincinnati Landing.

Hansen (1951:224), in his study of the biology of the white crappie, observed that crappie samples taken in hoop nets did not necessarily indicate the relative abundance of the two species. At Lake Chautauqua, near Havana, Illinois, he found that a dominance of black crappies or white crappies shifted in an erratic manner from week to week. In view of Hansen's study, the actual status of the species of crappie that is dominant in the test nets of a given section of river becomes uncertain. However, the constant dominance of the black crappie in catches during the three sampling periods at Grafton tends to substantiate the belief that it is more abundant there than the white. The dominance of the white crappie in most of the upper river collections between Winfield and Dubuque (1944 and 1946) indicates that this species is probably more abundant than the

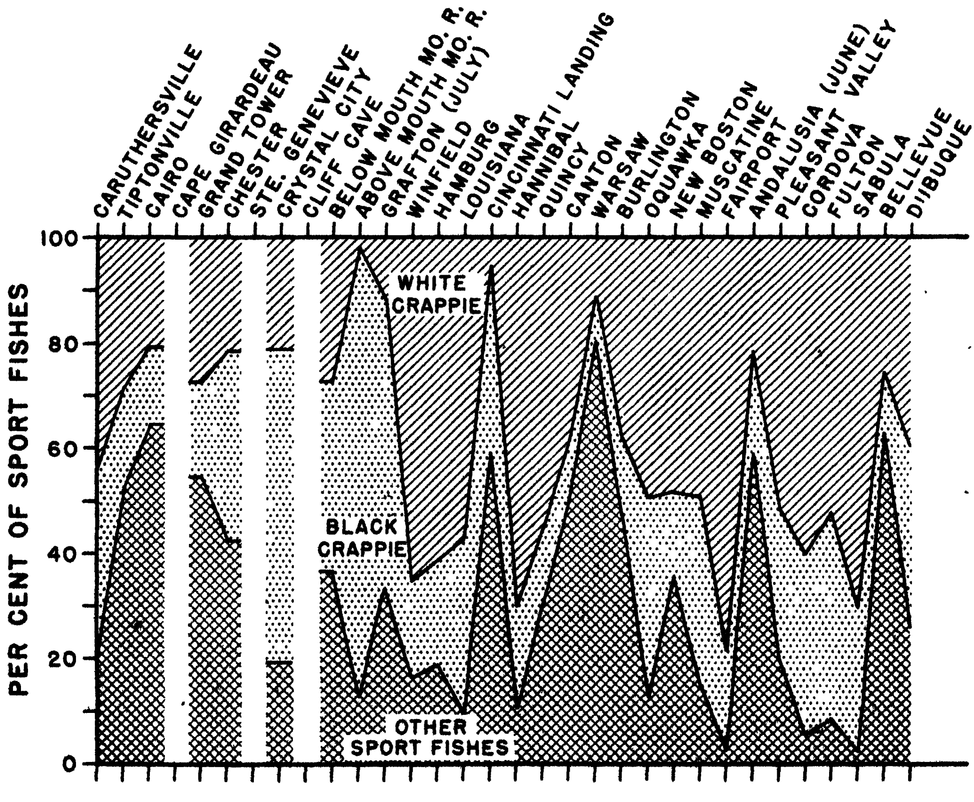

Fig. 15.—The relative abundance, as determined by test-netting, of the white crappie, black crappie, and other sport fishes at the various field stations on the Mississippi River between Caruthersville and Dubuque, 1944 and 1946. The percentages are based on the total number of sport fishes taken at each station. No sport fishes were taken at Cape Girardeau nor at Cliff Cave. The number taken at Ste. Genevieve, two, was considered too small to be significant.

Table 22.—Length-frequency distribution of the black crappie and the white crappie in test-net collections from the Mississippi River between Caruthersville, Missouri, and Dubuque, Iowa, in 1944 and 1946.

Total Length in Inches	Black Crappie			White Crappie		
	MR-C Section 1944	D-MR Section 1944	D-MR Section 1946	MR-C Section 1944	D-MR Section 1944	D-MR Section 1946*
2.8- 3 7....	—	—	56	—	—	32
3.8- 4.7........	—	3	257	1	7	463
4.8- 5.7............	1	21	149	—	40	394
5.8- 6.7.......	41	121	142	21	148	212
6 8- 7.7 ..	48	291	217	37	191	239
7.8- 8.7	18	369	194	34	219	392
8 8- 9.7 ...	11	418	288	17	147	446
9.8-10 7...	4	145	128	4	100	358
10.8-11 7....	—	21	16	3	24	152
11.8-12.7..	—	2	3	2	3	33
12 8-13 7 .	—	1	1	—	—	4
13 8-14 7 .	—	—	1	—	—	—
Total number...	*123*	*1,392*	*1,452*	*119*	*879*	*2,725*
Average length ..	7 3	8 4	7.1	7.9	8.0	7.5
Per cent 8 inches or more...	26 8	68 7	43 5	50.4	56.1	50.8

* D-MR 1946 data include 51 white crappies from a catch with a 1½-inch hoop net by J S. Barnett, a commercial fisherman at Oquawka, Illinois.

black in the D-MR section. Coker (1930: 202) found the white crappie was apparently about three times as abundant as the black at Keokuk.

The length-frequency distributions of the black crappies and white crappies taken in the test nets are presented in table 22. Slightly more than 50 per cent of the white crappies taken were 8 inches or more in length; with the exception of individuals taken in the 1944 D-MR section, a smaller proportion of the black crappies were of these lengths. Age and growth studies made from the scales of these fishes showed that the white crappies grew faster than the blacks, which probably accounts for the greater percentages of large white crappies.

It is difficult to determine the abundance of the largemouth black bass (*Micropterus salmoides*) from net and seine collections. As anyone who has attempted the netting of this bass realizes, it is not easily taken in numbers even where a large population may be present. Therefore, very little can be said regarding the status of the largemouth in the river. In the poisoning censuses of fish populations made in backwaters adjoining the Mississippi at Oquawka and Savanna, the largemouth population was rather low. Since these censuses pertain to only two localities, they do not necessarily indicate the overall status of the bass population. The largemouth black bass formed only an insignificant part of the test-net collections in the MR-C section in 1944 and of those in the D-MR section in 1946. In the D-MR section in 1944 the largemouth amounted to 1.4 per cent of the total number of fishes caught. Of these, 76.4 per cent were taken at Grafton. As was stated previously, some of the nets were set in bottomland lakes and sloughs of the Grafton area, long known as excellent for bass fishing. Anglers usually fish for bass in backwater lakes and sloughs of the Mississippi rather than in the river proper.

As shown in table 23, the average length of largemouth black bass taken in the test-net collections was more than 10 inches.

In each year of the survey, two spotted black bass (*Micropterus punctulatus*) were taken in the collections. This species of bass is too scarce in the Caruthersville-Dubuque section of the river to be of any importance to the sport fishery. The 1944 specimens were taken at Caruthersville and the 1946 at Fulton, Illinois.

No specimen of the smallmouth black bass (*Micropterus dolomieu*) was taken

in the test-net collections; however, one small specimen was taken with a minnow seine at Claryville, Missouri. The absence of this species from the test-net collections indicates that it is probably scarce in the area investigated, and that the largemouth is the only representative of the black basses that occurs in large enough numbers to be of any importance to the sport fishery.

The green sunfish (*Lepomis cyanellus*) appeared to be quite scarce in the Mississippi. In 1944, 18 fish of this species were taken in the test-net collections at Tiptonville and Crystal City, both MR-C stations. Only 3 were taken in test nets in the D-MR section in 1946. Green sunfish were taken in minnow seine collections at Louisiana, New Boston, Sabula, and Muscatine.

Table 23.—Length-frequency distribution of the largemouth black bass in test-net collections from the Mississippi River between Caruthersville, Missouri, and Dubuque, Iowa, in 1944 and 1946.

Total Length in Inches	MR-C Section 1944	D-MR Section 1944	D-MR Section 1946
6.8– 7.7	1	1	—
7.8– 8.7	1	2	1
8.8– 9 7	1	3	1
9.8–10 7	1	15	1
10.8–11 7	2	22	4
11.8–12.7	3	40	3
12.8–13.7	—	17	3
13.8–14 7	1	7	3
14.8–15 7	—	8	—
15.8–16 7	—	6	—
16.8–17.7	—	—	2
17.8–18 7	—	2	—
Total number	*10*	*123*	*18*
Average length	10 9	12 4	12 6

Table 24.—Length-frequency distribution of the bluegill in test-net collections from the Mississippi River between Caruthersville, Missouri, and Dubuque, Iowa, in 1944 and 1946.

Total Length in Inches	MR-C Section 1944	D-MR Section 1944	D-MR Section 1946
2.8– 3.7	—	—	6
3.8– 4.7	6	11	60
4.8– 5 7	.5	87	59
5.8– 6 7	20	231	75
6.8– 7 7	7	204	75
7.8– 8 7	—	23	33
8.8– 9.7	—	—	—
9.8–10.7	1	—	—
10.8–11.7	—	—	—
Total number	*39*	*556*	*308*
Average length	6.1	6.5	6.1

The orangespotted sunfish (*Lepomis humilis*) was not taken in the test-net collections; however, it was taken in minnow seine collections at Grafton and Warsaw. This species seldom attains a length of over 4 inches (Eddy & Surber 1947: 237) and it consequently has little value as a sport fish.

The flier (*Centrarchus macropterus*), according to Forbes & Richardson (1920: 242), is southern in distribution, "occurring in lowland streams and bayous of the lower Mississippi Valley, and in the south Atlantic region from Florida to Virginia." In the Mississippi survey one specimen of this species was taken in a minnow seine haul at Caruthersville and another in a test-net collection at Cairo. This species, like the orangespotted, does not attain a sufficient size to make it of much value as a sport fish.

The bluegill (*Lepomis macrochirus*) was taken at the majority of the survey stations. This species was collected in greater abundance in the D-MR section than in the MR-C. The largest collections of bluegills were taken at Grafton and Dubuque.

The average size of the bluegills collected, as shown in table 24, was over 6 inches. Such a size is usually considered by midwestern anglers as fair for bluegills. Age and growth studies on bluegills collected during the survey show that, on the

Table 25.—Length-frequency distribution of the warmouth in test-net collections from the Mississippi River between Caruthersville, Missouri, and Dubuque, Iowa, in 1944 and 1946.

Total Length in Inches	MR-C Section 1944	D-MR Section 1944	D-MR Section 1946
3.8–4.7	1	—	—
4.8–5.7	2	4	3
5.8–6.7	6	23	—
6.8–7 7	5	25	3
7.8–8.7	1	—	4
Total number	*15*	*52*	*10*
Average length	6.5	6.7	7 1

average, 6-inch fish were about 3 years of age, indicating rather slow growth.

The warmouth (*Chaenobryttus coronarius*), according to Coker (1930:204), was never very abundant in the Keokuk area of the Mississippi. This species was not taken abundantly anywhere during the Caruthersville-Dubuque survey. As in the case of the other sport fishes, the warmouth was taken more abundantly in the D-MR collections than in the collections farther south. It was taken less abundantly in the Burlington-Dubuque section than in the lower part of the D-MR section, that part surveyed in 1944.

Age and growth studies of specimens taken from the Illinois-Missouri section of the Mississippi in 1944 tended to show that growth of the warmouth, table 25, was a little slower than that of the bluegill. Bluegills 3 years of age averaged 6.64 inches, whereas warmouths of this age averaged 6.16 inches. The warmouth is probably not abundant enough in the Caruthersville-Dubuque section of the river to be considered of much importance to the sport fishery.

Sea Basses

SERRANIDAE

The white bass (*Lepibema chrysops*) and the yellow bass (*Morone interrupta*) are the only members of this large family, principally composed of marine fishes, occurring in the Caruthersville-Dubuque section of the Mississippi River. The white bass, according to Greene (1935:160), is more northern in range than the yellow bass. In this survey both species were taken at the lowermost station, Caruthersville, and only the white bass in the Dubuque collections; however, one specimen of yellow bass was taken at Bellevue, 17 miles below Dubuque, indicating that the species probably occurs at the geographic extremes of this survey. The test-net collections indicate that the white bass is more widely distributed than the yellow bass in that part of the river surveyed.

The white bass was taken in greater numbers than the yellow bass in the MR-C section of the river; however, neither species was common there. In the D-MR section both species were much more abundant than in the MR-C section, Appendix B. The white bass accounted for 2.19 per cent of the total number of all fishes in the 1944 D-MR collections, the yellow bass for 0.05 per cent. In the total catch at the stations fished in 1946, the yellow bass was one and one-half times as abundant as the white bass. This reversal in abundance was due to the large catch of yellow bass at New Boston, where 84.1 per cent of the 1946 catch of this fish was taken. One wing net (1-inch mesh) in a backwater area at New Boston produced 198 yellow bass, amounting to 91.2 per cent of the 217 yellow bass caught at this station. Sex determinations made of these fish revealed that 96.5 per cent were ripe males. From this catch it appears that the males possibly are attracted during the spawning season by a few ripe females in the net. A more nearly accurate picture of abundance and distribution of white bass and yellow bass in the D-MR section can be obtained when the New Boston figures are omitted from the 1946 data for both species. When this is done the white bass appears to be three times as abundant as the yellow bass. The abundance of these fishes in the upper river has been discussed by several investigators. In 1888 near Quincy, Garman (1890:137) found the white bass more abundant than the yellow bass, and, many years later at Keokuk, Coker (1930:207) found the white bass more common than the yellow bass.

The former status of these fishes in Illinois is discussed by Forbes & Richardson (1920:320). In discussing conditions of about 50 years ago these authors wrote the following regarding the white bass in the Mississippi: "It was formerly much more common than now. We are informed by Mr. H. L. Ashlock that a dozen years ago one could easily get a hundred pounds of it in an afternoon at Alton with a hundred-yard trammel-net, but that it has now almost disappeared." At the same time these authors (1920:321) found the yellow bass about twice as abundant as the white bass in Illinois.

The average sizes of the white bass and the yellow bass in the test-net collections differed only slightly, table 26. The white bass, however, attains greater sizes than the yellow bass. Both of these fishes

Table 26.—Length-frequency distribution of the white bass and the yellow bass in test-net collections from the Mississippi River between Caruthersville, Missouri, and Dubuque, Iowa, in 1944 and 1946.

Total Length in Inches	White Bass			Yellow Bass		
	MR-C Section 1944	D-MR Section 1944	D-MR Section 1946	MR-C Section 1944	D-MR Section 1944	D-MR Section 1946
3.8– 4.7	—	—	17	—	—	1
4.8– 5.7	—	10	23	—	—	3
5.8– 6 7	2	17	9	—	—	22
6.8– 7 7	6	30	13	1	—	18
7.8– 8 7	5	25	27	1	1	131
8.8– 9.7	5	18	19	—	3	68
9.8–10.7	—	41	17	—	—	9
10.8–11.7	1	24	22	—	—	5
11.8–12.7	2	9	10	—	—	1
12 8–13.7	1	7	3	—	—	—
13.8–14.7	2	9	—	—	—	—
14 8–15.7	—	2	2	—	—	—
15.8–16 7	—	1	—	—	—	—
Total number	*24*	*193*	*162*	*2*	*4*	*258*
Average length	9.2	9 4	8.4	7 8	9.0	8.4

are considered as excellent sport fishes, and they often form an important part of the angler's catch.

PREDATORY FISHES

In the present report the gars and the bowfin are grouped as predatory fishes. These fishes feed to a large extent upon other fishes and they have little commercial value. Many of the species designated in this report as commercial or sport fishes are also predatory in habits. The catfishes, black basses, and pikeperches are examples.

Gars

LEPISOSTEIDAE

The shortnose gar (*Lepisosteus platostomus*)* occurred much more frequently in the test-net collections than did the other species of gars. This gar was abundant in the MR-C and D-MR sections of the river.

The longnose gar (*Lepisosteus osseus*) also was common in both sections of the river; however, it occurred much less frequently in the test-net collections than the shortnose gar.

Eighty-five specimens of the alligator gar (*Lepisosteus spatula*) were taken during the survey. Of these, 84 were from the MR-C section. The single specimen from the D-MR section was taken at Grafton. As shown in Appendix B, table 1, in the MR-C section the alligator gar was netted at only four stations. Eighty of the 84 specimens were taken at Cairo. Forbes & Richardson (1920:35) state that: "The home of the alligator-gar is in the streams of the Gulf of Mexico, from Mexico to Cuba. It ascends the Mississippi above St. Louis, and has occasionally been taken in the lower Illinois River."

The length-frequency distribution of the gars taken in the test-net collections is given in table 27.

The largest gar taken during the survey was an alligator gar measuring 5 feet 5 inches total length and weighing 54.81 pounds. This specimen was taken in a 1-inch-mesh wing net at the Grand Tower station. The alligator gar, according to Dr. David Starr Jordan, reaches a length of 20 feet (Forbes & Richardson 1920: 35). The average length of the alligator gar in the MR-C collections was 23.5 inches, an average less than that determined for the longnose gar. The shortnose gar, as shown in table 27, averaged much less in length than the other gars.

In some areas gars are sought by anglers merely for sport. The larger specimens,

* In this investigation the spotted gar, *Lepisosteus productus* Cope, if present, was not separated from the shortnose gar.

particularly of alligator gars, provide a challenge to an angler using only moderately heavy tackle.

Bowfin

AMIIDAE

The bowfin in the Midwest is considered by some anglers as an excellent sport fish. This fish will, on occasion, strike a spinner-bucktail combination or a plug. The vicious runs of the bowfin after striking an artificial lure are something to be remembered, even by the experienced angler. The value of the bowfin as a food fish seems to be a debatable subject; however, the smoked flesh of a bowfin is considered a delicacy by some.

Fewer bowfins were taken in the collections from the MR-C section than in those from the D-MR section of the river. Catches of 41 bowfins at Winfield and 62

Table 27.—Length-frequency distribution of the gars and the bowfin in test-net collections from the Mississippi River between Caruthersville, Missouri, and Dubuque, Iowa, in 1944 and 1946.

Total Length in Inches	Shortnose Gar			Longnose Gar			Alligator Gar		Bowfin		
	MR C Sec. 1944	D-MR Sec. 1944	D-MR Sec. 1946	MR-C Sec. 1944	D-MR Sec. 1944	D-MR Sec. 1946	MR-C Sec. 1944	D-MR Sec. 1944	MR-C Sec. 1944	D-MR Sec. 1944	D-MR Sec. 1946
6.8-7.7	—	—	—	—	1	—	—	—	—	—	—
8.8-9.7	—	1	—	—	—	—	—	—	—	—	—
11.8-12.7	1	—	—	—	—	—	—	—	1	—	—
12.8-13.7	7	—	—	—	—	—	—	—	1	—	—
13.8-14.7	53	8	—	—	—	—	—	—	2	1	1
14.8-15.7	116	52	—	1	—	—	1	—	—	3	1
15.8-16.7	108	87	9	—	—	—	—	—	3	4	3
16.8-17.7	51	102	6	2	2	1	—	—	4	11	5
17.8-18.7	38	123	7	2	16	1	—	—	2	8	6
18.8-19.7	32	119	30	2	20	1	2	—	4	12	20
19.8-20.7	18	109	32	2	8	3	3	—	8	14	32
20.8-21.7	37	91	45	2	7	1	7	—	2	5	34
21.8-22.7	26	59	33	2	6	3	26	—	1	9	24
22.8-23.7	36	29	26	—	13	1	19	—	—	3	12
23.8-24.7	33	19	15	—	7	5	14	—	—	2	5
24.8-25.7	26	5	4	1	11	6	7	—	—	4	5
25.8-26.7	11	1	1	—	13	1	3	—	—	1	3
26.8-27.7	8	3	1	2	4	2	1	1	—	1	3
27.8-28.7	1	1	—	1	5	3	—	—	—	2	—
28.8-29.7	—	—	—	4	3	3	—	—	1	1	—
29.8-30.7	—	—	—	2	6	1	—	—	—	—	—
30.8-31.7	—	—	—	—	3	1	—	—	—	—	—
31.8-32.7	—	—	—	6	1	—	—	—	—	—	—
32.8-33.7	—	—	—	1	1	—	—	—	—	—	—
33.8-34.7	—	—	—	3	2	—	—	—	—	—	—
34.8-35.7	—	—	—	4	3	1	—	—	—	—	—
35.8-36.7	—	—	—	4	2	—	—	—	—	—	—
36.8-37.7	—	—	—	2	1	—	—	—	—	—	—
37.8-38.7	—	—	—	1	—	—	—	—	—	—	—
38.8-39.7	—	—	—	—	1	—	—	—	—	—	—
39.8-40.7	—	—	—	2	2	2	—	—	—	—	—
40.8-41.7	—	—	—	3	3	—	—	—	—	—	—
41.8-42.7	—	—	—	—	—	—	—	—	—	—	—
42.8-43.7	—	—	—	1	1	—	—	—	—	—	—
43.8-44.7	—	—	—	—	1	—	—	—	—	—	—
44.8-45.7	—	—	—	—	—	—	—	—	—	—	—
45.8-46.7	—	—	—	1	—	—	—	—	—	—	—
46.8-47.7	—	—	—	—	—	1	—	—	—	—	—
50.8-51.7	—	—	—	—	—	1	—	—	—	—	—
64.8-65.7	—	—	—	—	—	—	1	—	—	—	—
Total number	*602*	*809*	*209*	*51*	*143*	*38*	*84*	*1*	*29*	*81*	*154*
Average length	18.5	19.1	21.1	30.6	24.8	27.1	23.5	—	18.7	20.3	21.1

Table 28.—Length-frequency distribution of the goldeye, the mooneye, and the gizzard shad in test-net collections from the Mississippi River between Caruthersville, Missouri, and Dubuque, Iowa, in 1944 and 1946.

Total Length in Inches	Goldeye	Mooneye		Gizzard Shad	
	D-MR Section 1946	D-MR Section 1946	MR-C Section 1944*	D-MR Section 1944	D-MR Section 1946
2.8- 3.7	—	—	—	7	1
3.8- 4.7	—	—	1	9	26
4.8- 5.7	2	31	3	35	72
5.8- 6.7	18	22	24	12	13
6.8- 7.7	12	52	21	27	7
7.8- 8.7	8	38	31	50	26
8.8- 9.7	7	19	32	35	28
9.8-10.7	7	9	43	86	22
10.8-11.7	12	2	28	146	8
11.8-12.7	2	1	28	184	6
12.8-13.7	2	—	23	126	8
13.8-14 7	5	—	18	62	10
14.8-15.7	6	—	6	22	4
15.8-16.7	—	—	5	4	6
16.8-17.7	3	—	1	—	—
Total number	*84*	*174*	*264*	*805*	*237*
Average length	9.7	7.4	10.3	11 2	8 0

* The goldeye was not separated from the mooneye at all of the 1944 stations and was included with the mooneye in the 1944 data.

at Fulton were the largest taken at any of the stations. Both of these stations were in the D-MR section. The average lengths of the specimens taken in the test-net collections are shown in table 27.

FORAGE FISHES

The forage fishes are of little or no commercial value, but they serve as food for other fishes. They are usually very numerous as compared with the predatory fishes that feed upon them. Minnows (Cyprinidae) and the gizzard shad (*Dorosoma cepedianum*) are quite abundant in the Mississippi River and undoubtedly serve as food for many of the carnivorous fishes. The term forage fishes as applied here in not particularly satisfactory since the specimens caught in nets were too large to serve as prey for all but very large carnivorous fishes.

The various species of minnows taken during the survey were caught in most cases with a minnow seine; catches with this gear are not considered in this paper.

The goldeye (*Amphiodon alosoides*) and the mooneye (*Hiodon tergisus*), included with the forage fishes in 1944 and with the commercial fishes in 1946, Appendix B, lack commercial importance in the MR-C section and parts of the D-MR section. The goldeye was not separated from the mooneye at all the 1944 stations and was included with the mooneye in the 1944 data, Appendix B, table 1. In the 1946 survey these two species were separated, table 15 and Appendix B, table 2. The mooneye was taken in much greater abundance than the goldeye in the 1946 collections. These two species formed a more important part of the catch in the Burlington-Dubuque section of the river than they did in the parts of the river fished in 1944. The length-frequency distribution of the goldeye and mooneye is given in table 28. As indicated by this table the goldeyes were of larger sizes than the mooneyes. Neither of these species was collected in sufficient numbers to indicate that they are of potential importance as commercial fishes in the Caruthersville-Dubuque section of the river.

Only two specimens of the golden shiner (*Notemigonus crysoleucas*) were taken in the test-net collections. They were collected in 1944 at Grafton.

The gizzard shad formed a much more important part of the test-net catch in 1944 than it did in 1946. Along with the drop in the 1946 catch of gizzard shad, table 28, there was also a noticeable reduction in size of these fish. In two backwater areas poisoned in 1946, near Savanna, there were low populations of gizzard shad; only 196 individuals per acre and an average of 4.69 pounds per acre were recovered. Two similar backwater areas poisoned in 1947, near Oquawka, contained a per acre average of 8,201 gizzard shad that in the aggregate weighed 284.5 pounds.

The gizzard shad is so bony that it is seldom used as a food fish by man; however, when small it is considered as an important link in the food chain of other fishes.

The skipjack (*Pomolobus chrysochloris*) was taken occasionally in the collections between Caruthersville and Warsaw. No specimen was collected above Warsaw. Coker (1930:169) noted that during the first few years following construction of the power dam at Keokuk the abundance of the skipjack declined rapidly in the upper part of the river. He presented evidence to show that the skipjack is migratory but does "not necessarily go to extreme northern or extreme southern waters, and that the breeding places from which the upper river was formerly chiefly stocked are no longer accessible to a great number of herring (skipjack)." Eddy & Surber (1947:91) state that the skipjack is very rare, if not extinct, above the Keokuk dam. The scarcity of the skipjack in the collections of the 1944 survey tends to indicate that this fish may have been affected by the locks and dams constructed below Keokuk since the time Coker made his studies on the river.

The skipjack is too bony to be of much value as a food fish; however, it is considered by some anglers as a very gamy fish when taken on light tackle. The importance of the skipjack, according to Coker (1930:166), is as a host for the young (glochidia) of the niggerhead mussel. This mussel was formerly of great economic importance to the button industry, but appeared to decline in abundance with the decrease of the skipjack in the upper river.

DISCUSSION

Poor land management in the upper Mississippi drainage basin has changed the section of the river from Dubuque to the mouth of the Missouri from a clear to a coffee-colored stream in less than a century. With the promotion of drainage schemes under the guise of agricultural development, the Mississippi River was leveed out of most of its natural flood plain reservoirs, which were evidently once the spawning and rearing grounds of many fishes. This encroachment upon the flood plain of the river by man, combined with intensive agricultural practices in the uplands, has brought about many of the present flood control problems. The canalization of the upper river evidently is responsible for the disappearance or reduction in numbers of certain fishes and has produced fisheries problems associated with draw-downs and silt-laden navigation pools. City and manufacturers' wastes also have contributed to the deterioration of the river as a fish habitat.

Although commercial fishing may have contributed to the reduction of certain fishes, the decline in the fishery as a whole appears to have followed the change in habitat rather than any intensification of commercial fishing activities. Such findings given in this paper as pertain to the abundance, size, and maturity age of the important commercial and sport fishes may be of some value in developing fishing regulations that are biologically sound. However, the problem of the Mississippi River fishery is more than one of legal restrictions. Perhaps legal restrictions will aid some species, but, with an environment that is unfavorable, other species probably will continue to dwindle. The decline in the catch of the buffalofishes, catfishes, pike, sturgeons, paddlefish, and others has been pointed out. The future of the paddlefish and the blue sucker appears in doubt. The status of the freshwater eel and the skipjack has been seriously affected, probably by the installation of locks and dams in the upper river. Perhaps other fishes have been and will be affected by the dams.

The differences in the abundance of fishes in the several parts of the pools, as evidenced by the 1946 test-net collections,

clearly demonstrate the effect canalization has on the habitat in the river. Evidently the silt-covered bottoms and reduced currents observed in the lower and middle reaches of the pools are less favorable for many species, particularly of the sport fishes, than conditions existing in the upper reaches. On the other hand, some of the impoundments have provided more backwater areas, which are usually considered favorable to fish production. The inundation of forest land has resulted in the formation of habitat containing hollow logs, suitable for catfish spawning.

The MR-C section of the river appeared to be much less productive of fish than the D-MR section. Greater scarcity of spawning grounds, turbidity of water, and swiftness of current in the MR-C section, as compared with the D-MR section, appear to be factors accounting for some of the productivity differences of the two sections. These factors are reflected in the distribution and abundance of sport fishes in the test-net collections.

Since the end of the last century the catch of carp has annually compensated for some of the losses in poundage of declining species. Commercial values of carp, however, are not so high as those of some of the declining species. Some of these losses might be compensated for if proper utilization could be made of certain abundant species in the river. Crappies, particularly the white, are quite abundant in the D-MR section of the river. Probably only a small portion of these fishes are taken annually by anglers. Crappies are not a long-lived fish, and as a result most of this resource is lost. The commercial fishery would benefit if crappies were placed on the commercial list, since these fishes are netted easily and would bring a good price. It is doubtful if commercial fishing would deplete the crappie population to such an extent that the sport fishery would suffer. Reduced crappie populations might permit better growth and furnish anglers with larger fish than are now being taken.

Development of better methods for handling river carpsuckers in warm months would benefit commercial fishermen.

The smoking of carp and bowfins has possibilities of further increasing values of these fishes.

Poor fishing in some instances may be a result of the decrease in natural predators (Bennett 1947:278). In the Mississippi River gars may be important predators. These fishes are possibly filling a gap left by the decreases in populations of pike, yellow pikeperch, and fish-eating ducks. Further biological studies on gars might establish the possibility that gars are beneficial to the fishery rather than harmful, as is commonly believed by fishermen.

SUMMARY

1. A survey of the fishes occurring in the Mississippi River between Caruthersville, Missouri, and Dubuque, Iowa, was made in 1944 and 1946. Thirty-one sampling stations were used. The following types of commercial fishing gear were employed: 25-foot *Common Sense* minnow seines, 100-yard trammel nets, 100-yard seines, hoop nets, wing nets, trap nets, basket traps, and trotlines.

2. The lengths and weights of fishes and the condition of their gonads were recorded afield for all individuals captured in the test nets. The length-frequency distribution of the more abundant fishes was recorded in tabular form. Altogether 26,037 fishes having a total weight of 28,294.25 pounds were taken in the 1944 and 1946 operations.

3. Observations on the various species of fishes taken by test netting were recorded. The numbers and weights of fishes caught at each station were listed by species, Appendix B.

4. Characteristics of the Mississippi River and the sampling stations were studied. Comparisons were made, in relation to the habitat and fishery, between two sections of the Mississippi River: one extending from Dubuque to the mouth of the Missouri River (D-MR section) and the other from the mouth of the Missouri to Caruthersville (MR-C section).

5. The carp, freshwater drum, flathead catfish, channel catfish, carpsuckers, smallmouth buffalo, shortnose gar, longnose gar, and gizzard shad were taken abundantly from both sections of the river.

6. The blue catfish, alligator gar, black bullhead, and black buffalo were collected principally in the MR-C section.

The alligator gar was taken only once in the D-MR section.

7. Sport fishes, bigmouth buffalo, and channel catfish were taken more abundantly in the D-MR section than in the other section.

8. Carp, buffalofishes, catfishes, carpsuckers, and freshwater drum were the most abundant commercial fishes taken during the survey. The shovelnose sturgeon was found to be the only sturgeon still abundant enough in the river to be of any commercial importance. The paddlefish was much less common than formerly.

9. The blue sucker, skipjack, and American eel were not numerous at any of the sampling stations. The skipjack was not taken above Warsaw, Illinois.

10. The crappies were the most abundant game fishes in the test-net collections. The black crappie was taken more abundantly than the white between the mouths of the Illinois and Missouri rivers. Above the mouth of the Illinois the white crappie was taken more abundantly than the black. The bluegill was second in abundance to the crappies among the game fishes. The sauger was collected in greater abundance than the yellow pikeperch (walleye). The yellow pikeperch was not taken in the MR-C section. No specimen of yellow perch was taken, although old records list this species as once fairly common in the sections of the river surveyed. White bass were more abundant than yellow bass.

11. Fishes, particularly game fishes, were collected more abundantly in the upper reaches of the navigation pools than in the middle and lower reaches.

12. The principal factors limiting the Mississippi River fishery are related to soil erosion of the watershed, levee and drainage works, and industrial and municipal pollution.

APPENDIX A

MISSISSIPPI RIVER FIELD STATIONS

BELOW are descriptions of the Mississippi River field stations at which test-net fishing was done in 1944 and 1946 between Caruthersville, Missouri, and Dubuque, Iowa.

Following the name of each station is the designation of the section of the river in which the station was located and the dates on which test-net fishing was done at the station. MR-C designates that section of the Mississippi River between the mouth of the Missouri River and Caruthersville; D-MR designates that section between Dubuque and the mouth of the Missouri River.

1.—**Caruthersville, Missouri** (MR-C section, April 6–12, 1944). The river at this station was at flood stage and out of its banks. Nets were set along the Missouri bank of the river wherever possible. Also nets were set in a large levee borrow pit, the water of which, as a result of the flood, was continuous with the water in the main channel. To enter the borrow pits, the powered fishing boat passed over a barbed wire fence without difficulty. Toward the end of the sampling period the river receded, and two nets were set in small streams connecting the borrow pit with the river channel. The river dropped enough to allow making several minnow seine hauls on sand bars near the ferry landing on the Tennessee side of the river. At the time of departure of the fishing boat from Caruthersville the river had again begun to rise.

2.—**Tiptonville, Tennessee** (MR-C section, April 15–May 10, 1944). Here the river was at flood stage, and the flood was considered locally as of major proportions. A small fleet of United States Army Corps of Engineers boats and the Tiptonville ferry were moored in a slough close to the town of Tiptonville and approximately three-quarters of a mile from the river channel. Normally this slough is dry for part of each year. The current at this station was swift. Towboats carrying loaded barges upstream were unable to push their entire complements of barges. Instead they pushed half their tows to points upstream, where the barges were tied up to trees or other stalwart objects; then the towboats returned downstream to pick up the remaining barges.

Because of mechanical difficulties the expedition was delayed here for about 20 days.

It was impossible to set nets in or near the river channel. All sets were made in flooded cornfields or cotton fields or within the margin of woody vegetation adjacent to the river channel. Several of the net sets were made in a flooded slough in which the *Anax* and other boats were moored, and in a temporarily inundated, shallow levee borrow pit. The disparities in habitats fished at this station were too great to make the data comparable to those of other stations. However, it appears logical to assume that fish normally confined to the river channel were distributed temporarily over a large expanse of water. The river was reported unofficially to have been 3 miles wide at Tiptonville during the flood.

3.—**Cairo, Illinois** (MR-C section, May 18–24, 1944). At this station, the water was high but it fell more than 13 feet during 5 days of netting. On the Illinois side of the Mississippi River, levees have been built to protect the city of Cairo. The levees on the Missouri side are some distance back from the river.

Sampling was done on the Illinois side of the Mississippi, 5 to 6 miles above the mouth of the Ohio River, just above Cairo, in shallow water adjacent to and within 50 to 100 yards of the river channel, and in a levee borrow pit. The rapid fall in water level necessitated moving the nets to deeper water nearly every day.

4.—**Cape Girardeau, Missouri** (MR-C section, May 26–31, 1944). Netting was done along both banks of the river just south of Cape Girardeau in an area called Cape Bend. There were several sand islands here, covered mainly with willows, and a number of log jams. Several wing nets with leads were set at the mouth and several 100 yards up the Little River Diversion Canal. This

canal lies at the upper end of a huge drainage system that covers the entire southeast section of Missouri, including the so-called "boot heel."

5.—Grand Tower, Illinois (MR-C section, June 2–9, 1944). The river stage was high here, as at Cape Girardeau; however, it is believed that fishing at this station was not so greatly influenced by high water as at stations below Cape Girardeau.

Nets were set along the Grand Tower waterfront and in the chute around the east side of Grand Tower Island. The current in the chute around the island was strong. At normal river stage the flow in the chute around Grand Tower Island is supposed to be much reduced and at times it is cut off entirely.

Because of the narrow constriction in the river channel just above Grand Tower, the current in the main channel (and in the chute around the island during flood stage) is very swift. The Missouri bank of the river at this station is a precipitous rock bluff, and the low flood plain on the Illinois side is subject to flooding even at a moderately high stage of water. Vegetation along the Illinois shore and on the island consists principally of willow and cottonwood. During the work at this station, early in June, typical warm summer weather began.

6.—Chester, Illinois (MR-C section, June 11–15, 1944). The river was high during the sampling period at this station. Nets were set in the vicinity of Horse Island at the mouth of Old River and several miles up Old River in the vicinity of Kaskaskia Island. At these locations the current was swift. Some netting was done in quiet backwaters just above Chester and across the river from Menard, Illinois. The Missouri side and Kaskaskia Island are in levee districts. Minnow seining was done in the vicinity of Claryville, Missouri.

7.—Ste. Genevieve, Missouri (MR-C section, June 18–24, 1944). Netting was done on both sides of an island almost across the river from Ste. Genevieve. Minnow seining was done in shallow water along the shore line of two islands at Ste. Genevieve. (See section on "Pollution" regarding this station.)

8.—Crystal City, Missouri (MR-C section, June 25–30, 1944). The river stage was higher at this station than at Ste. Genevieve. The river was backed up in Platin Creek enough to provide harbor for a fleet of large quarter boats operated by the United States Army Corps of Engineers.

Fishing operations were carried on in Platin Creek—from 200 to 300 yards from its mouth to about a mile from its mouth—and in the river between Platin Creek and Hug Landing. The mouth of Platin Creek is just below the city limits of Crystal City, and Hug Landing is a mile distant, just above Crystal City. Nets were set along the Missouri shore of the river. Here the bank is low, but steep, and bordered by a narrow margin of willows and cottonwood trees.

At the upper net sets in Platin Creek the water was clear, and aquatic vegetation was present. Because of the high river stage, there was virtually no flow in the creek here. The creek was about 100 feet wide at this upper point and it was nearly bank full. It was well shaded by overhanging trees. Minnow seine hauls were taken in Platin Creek.

9.—Cliff Cave, Missouri (MR-C section, July 2–8, 1944). The river stage was high at this station. Netting was carried on between Cliff Cave and White House Creek on the Missouri side of the river and at the mouth of Columbia Creek on the Illinois side. This stretch covered about 4 miles by river channel. Most of the sets were made among small, partially submerged willows. Minnow seining was done around sand bars formed in the river along the Illinois side just below the Jefferson Barracks Highway Bridge and in shallow water along the Missouri side just below the submarine cable crossing.

10.—Mouth of Missouri River, Missouri (MR-C and D-MR sections, July 10–15, 1944). The mixing of the waters of the Missouri and the Mississippi rivers presents an impressive sight. As the water of the muddy Missouri billows into the Mississippi it appears like rolling clouds of smoke against a clear sky. The water of the Mississippi is far from clear, but that of the Missouri is so much more turbid that the contrast is quite marked.

Netting was divided into two units at this station. Equivalent numbers of wing nets and hoop nets were operated at two stations, one above and one below the mouth of the Missouri River. The nets operated below the Missouri River were set along the

Missouri shore between the mouth of the Missouri and the Chain of Rocks Bridge. The nets operated in the upstream unit were set along the Missouri shore in the vicinity of Mobile Island. At the time netting operations were begun here, the river was high, nearly bank full. While netting was being done at this station the water receded considerably.

11.—Grafton, Illinois (D-MR section, March 22–30, July 17–25, and September 22–27, 1944). Grafton was used as the key station during 1944. It was the lowermost station in the impounded section of the river. Obviously, certain physical characteristics of the river at Grafton vary considerably from those of the unimpounded river, which begins just below Lock and Dam No. 26 at Alton, Illinois.

At the lower ends of navigation pools in the impounded section, the river assumes some of the characteristics of a lake. It is somewhat comparable in appearance to the MR-C section in flood stage, although it lacks the swift current that usually accompanies flood waters. In the upper few miles of these pools the river appears to have more nearly the characteristics of a large river—somewhat swollen or slightly out of bank but with moderate current velocity. The velocity of the current in the pool is dependent upon the operation of the dam that creates this pool as well as the dam at its upstream reach. The operation of each dam, that is, the position of the gates, depends upon the volume of water to be passed down the river or the amount required for the maintenance of a 9-foot channel for navigation.

Fishing operations at the Grafton station during March were carried on primarily in the sloughs and lakes adjoining the last few miles of the Illinois River. Since the fish habitat in these lakes and sloughs differed widely in appearance from that in the Mississippi River, it is assumed for two reasons that the catch of fish in this area was not typical of that in the Mississippi. First, the water of this area was relatively clear as compared with that of the Mississippi, and, second, the lakes and sloughs had no current, although they were connected directly with the Illinois River channel.

Most of these lakes and sloughs were marked by a tangle of fallen and decaying trees, some by the remaining stumps of a once dense river-bottom forest. Some were merely enlargements of water areas that were present before the Alton dam was built. Others were bodies of water created by the impoundment.

In March, net sets were made on the Illinois side of the Mississippi River just below the mouth of the Illinois River along the waterfront at Grafton; sets were made on the Missouri side of the river off the northwest shore of Perry Island and in the lower end of the small chute between Perry Island and the mainland. The water-level was at full-pool stage and the current was slow as compared with that of the unimpounded waters below Pool No. 26. Although a definite routine of lifting all the nets each day usually was followed, it became impossible on the Missouri side of the river when for 2 days extremely high winds prevented the lifting of nets there.

In the July sampling period at Grafton, most of the fishing effort was concentrated in the Mississippi River, although some test netting was done in the backwater sloughs and lakes between the Illinois and the Mississippi, in which netting had been done in March. In July, sets were made on the Illinois side of the Mississippi along steep-sided earth banks between Squaw Island and Calhoun Point, and on the Missouri side of the river along the northwest shore of Perry Island and the gently sloping Missouri shore approximately a mile above. The water-level of the area was at full-pool stage. It appeared to be the policy of the Army Engineers to maintain Pool No. 26 at or near full level.

The operations at this station in September were similar to those in July. The net sets were made in approximately the same locations.

12.—Winfield, Missouri (D-MR section, July 27–August 2, 1944). Fishing operations at this station were carried on primarily below Lock and Dam No. 25, although two or three nets were set for several days in the pool above the dam, fig. 2. The nets operated below the dam were set along the east side of Maple Island, on the Illinois side near the Winfield ferry landing, and on the Missouri side in Cuivre Slough, at the upper end and channel side of Turkey Island, and at the mouth of Bobs Creek.

Farm land on the Missouri side of the river in this section is low and is subject to

flooding. It is maintained in an arable condition through a series of drainage districts and levees.

13.—Hamburg, Illinois (D-MR section, August 3–9, 1944). A number of years ago, Hamburg was an important shipping center for Calhoun County apples. It and a great number of other small towns along the river were important during the days of packet steamers when river shipping was the main activity of many of these towns. Now there is virtually no shipping from any of these towns except those having grain elevators located to fill barges. Outside of grain shipping, commercial fishing is probably the only industry associated with the river.

Netting at the Hamburg station was in about the middle of Pool No. 25. Nets were set in Westport Chute, around Kelly Island, in Thomas Chute, and in the mouth of Bryants Creek. The main channel is divided at the head of Westport Island, and part of the flow is carried by the Westport Chute. Although the water is deflected away from Westport Chute by wing dams, it is rather deep there. It carries enough current to allow the operation of hoop nets. Wing nets were set along the west margin of the chute and near the head of Westport Island. The narrow strip of land between Westport Chute and the Elsberry Drainage District Levee was low and swampy and was dissected by several sloughs; the entire area was covered by a dense growth of willow and cottonwood trees. Other net sets were made on the east shore of Westport Island, where the current was moderately swift. The sets around Kelly Island were located over a sandy bottom. Several seine hauls were made on a long, wide sand bar extending in an upstream direction from the head of Westport Island.

An extensive area along the river a few miles above Hamburg is wide river-bottom bordered on the Illinois side by high bluffs. The Illinois bottom area, which lies at the lower end of Sny Island Levee and Drainage District, is dissected by sloughs, backwater lakes, and the Sny. This area was once considered excellent for waterfowl.

14.—Louisiana, Missouri (D-MR section, August 12–17, 1944). This station was located in the middle section of Pool No. 24, fig. 3. Nets were set on the Illinois side of the river below the Alton Railroad bridge and in a cove just above the highway bridge; on the Missouri side of Blackburn Island, in the mouth of Salt River, and at the lower end of Angle Island. The areas above the railroad and highway bridges were essentially identical. Both were shallow backwaters in the lowland between the Illinois levee and the river channel. Before the construction of Lock and Dam No. 24, the areas were in dense growth of small woody vegetation, but at the time of the survey only stumps remained.

In Salt River the nets were set about one-fourth to one-half mile above its mouth. There was very little flow in the stream in this area.

15.—Cincinnati Landing, Illinois (D-MR section, August 19–23, 1944). Netting operations were carried out here in the upper section of Pool No. 24, within an approximate radius of 2 miles below Lock and Dam No. 22, fig. 4. Nets were set in a slough near Taylor Island. This slough, which carried a moderately swift current, produced the first adult blue sucker taken in 1944. Sets were made also in the narrow neck of water between Cottel Island and the mainland just below the Saverton Dam. The navigation channel shores of these islands consist of heavy sand deposits, which are typical of the channel shores below the locks and dams. Between Cottel and Taylor islands was a broad expanse of water which covered a continuous sandy bottom to a depth ranging from 2 to 3 feet.

16.—Hannibal, Missouri (D-MR section, August 25–30, 1944). Netting operations were carried on here in the vicinity of Glaucous Island, which is about 2 miles above Hannibal. This area is in the middle section of Pool No. 22, 13 miles below Lock and Dam No. 21. Nets were set in the slough between Glaucous Island and the Missouri shore and on the channel side of Glaucous Island. The slough was approximately 150 yards in width and in some places reached a depth of 10 feet or more. At other points it was quite shallow. Along most of the Missouri shore of the slough, the bottom sloped off abruptly into deep water. Some of the sets on the channel side of the island were made in deep water and others in relatively shallow bays. The current here was moderately swift.

17.—Quincy, Illinois (D-MR section, September 2–6, 1944). The Quincy station was located at the upper end of Pool No. 22,

about 3 miles below Lock and Dam No. 21. Nets were set in a slough between two islands (Ward Island and Island No. 432) and the Illinois shore. This slough was typical of river backwaters, having mud banks and shallow water. The river-channel shore, or the west shore, of Ward Island was covered by deposits of sand and protected by a number of wing dams. The current in the river channel opposite Ward Island was quite swift.

Minnow seining was done along the river-channel side of Ward Island, Island No. 432, and a small unnamed island just below 432.

The main pumping station for the South Quincy Drainage and Levee District is located just outside of the levee at the head of Island No. 432. During high river stages, this station pumps water from a network of lakes and drainage ditches on the outside of the levee. It was reported locally that these ditches and lakes furnish good bass and crappie fishing at certain times of the year. During the stay of the survey party here in 1944, this area was fished by a large number of sport fishermen from Quincy.

18.—Canton, Missouri (D-MR section, September 8–13, 1944). This station was located in the upper end of Pool No. 21. Test-netting was done at the head of Canton Chute along the east shore of Island No. 416, in Smoots Chute, and along the west shore of Island No. 416. Several nets were set along the Missouri shore below the Canton waterfront. The water in Canton Chute was quite clear as compared with that of the river channel, and the current in the chute was relatively slow. Canton Chute carries drainage from the Lima Lake Drainage District through Bear Creek diversion channel. While the survey party was at this station, the upper part of Canton Chute was being dredged, apparently for the purpose of facilitating drainage of water from the lowland on the Illinois side.

The upper end of Canton Chute is bordered by low but steep mud banks, which apparently are characteristic throughout its length. The connecting channel between the upper end of Canton Chute and the main stem of the river has a sandy bottom, and the shores of the upper end of Island No. 416 are covered with heavy deposits of sand. The channel into Canton Chute is flanked on its upstream side by a large, broad sand bar which obstructs the flow of water from the river channel into Canton Chute. The upper end of Island No. 416 is only a little more than a mile below Lock and Dam No. 20, and, as with similar formations in the upper reaches of other pools, the islands and shore line are characterized by deep deposits of sand. In fact, some of the islands are nothing more than large sand bars. The wing dams opposite the west shore of Island No. 416 are permanent rock structures. It appears that, in the canalized section of the river, the temporary wing dams constructed of piling are being replaced with permanent rock structures. Since it seems to be characteristic of the temporary wing dams in the lower river to collect great piles of driftwood that tend to create deep water holes just downstream from these dams, it might be that the temporary structures offer cover for fishes which the permanent ones do not. Large deposits of sand were found near the permanent structures, but no driftwood. The water flows between the piles of the temporary dams, while it is completely deflected around the permanent ones. Consequently, driftwood is washed away from the permanent dams but is pinned against and above the temporary ones by the force of the current.

19.—Warsaw, Illinois (D-MR section, September 14–19, 1944). This was the uppermost point on the river studied in 1944. Here netting operations were conducted in the upper part of Pool No. 20: along the Iowa border in the vicinity of the mouth of the Des Moines River and around Island No. 404 above the city of Warsaw; along the Missouri border below Alexandria and in the upper end of the slough between Fox Island and the mainland.

The current was quite sluggish near the mouth of the Des Moines River. The Mississippi from just above the mouth of the Des Moines to the head of Fox Island is confined by steep mud banks, which are protected from erosion by riprapping at several places. The shore line of Island No. 404 and the islands below Keokuk Dam (Lock and Dam No. 19) are covered with deep deposits of sand. The slough between Fox Island and the Missouri mainland carries a moderately swift current and is bordered on both sides by mud banks.

The upper end of Pool No. 20 is subject

to daily fluctuations of approximately 12 inches resulting from the operation of the Keokuk Dam, which, with its hydroelectric plant, was constructed by the Union Power and Light Corporation. Power produced at Keokuk is used to supplement production at other plants, and this plant is operated only during the day. Consequently, at the end of a day's operation, when the turbines are shut off, the flow of water through the dam is decreased, and the water level in the upper part of Pool No. 20 recedes. Operations at the dam are resumed daily, and by noon the water level in Pool No. 20 has again reached the maximum of the previous day. While this daily fluctuation may not affect the fish population, it does, however, affect the method of fishing. Coker (1914, 1929, 1930) made detailed studies of the effects this dam has had on the local fishery at Lake Keokuk, Pool No. 19.

An earlier discussion of the Warsaw station is included under the section titled "Pollution."

20.—Burlington, Iowa (D-MR section, April 10–22, 1946). This station was about 40 miles upstream from the uppermost area worked in 1944. It was located in the middle section of Pool No. 19, 9 to 15 miles below Lock and Dam No. 18 and 2 to 8 miles below the city of Burlington.

The river stage at the time test netting was begun was lower than in the previous week and it continued to fall during the sampling period here. However, the water level was still quite high, and much of the netting was done in backwater lakes and sloughs that are normally dry later in the season. Netting operations were confined largely to an area just above the mouth of Skunk River in the vicinity of Sullivan Slough and the lower end of Burlington Island. The bottom here was mud, and the water, which had little or no current, varied in depth from 3.5 to 6.0 feet. Some sets were made in the river channel. Trammel netting was carried on by drifting the net in the channel downstream. This type of fishing was conducted at stations having clean sand bottoms and water with current and with depths of 5 to 15 feet.

21.—Oquawka, Illinois (D-MR section, April 24–May 5, 1946). The river between Oquawka and Keithsburg, a distance of 12 miles, was dotted with many islands and sloughs. The west side of the river here was backed by an extensive levee system forming several drainage districts. The sloughs and backwaters on the Illinois side created good habitat for fish, particularly the sport species. This area was quite similar to the Grafton station described earlier. Above Keithsburg and below Oquawka both sides of the river were backed by levees. According to a local commercial fisherman the current in the river here had been greatly reduced since the installation of Lock and Dam No. 18. Nets were set several miles above Oquawka, in a chute formed by Benton Island, and also below Oquawka, in a chute formed by Island No. 369.

Beginning on September 8, 1947, two poison censuses of fish inhabiting two of the backwaters of this station were made. The backwaters poisoned were sloughs of 1.07 and 1.76 acres.

22.—New Boston, Illinois (D-MR section, May 7–18, 1946). This station was located in the upper section of Pool No. 18, just above New Boston. The mouth of the Iowa River is directly across the Mississippi River from New Boston. On the Iowa side of the Mississippi, netting was done in the chutes above and below the mouth of the Iowa River. Here the current was strong, the water varied in depth from 5 to 10 feet, and the bottom was of mud. On the Illinois side nets were set in the impounded backwaters in the Boston Bay area. A fairly swift current existed here from the discharge of the pumping station of the Bay Island Drainage and Levee District.

23.—Muscatine, Iowa (D-MR section, May 19–30, 1946). This station, located several miles below Muscatine, extended from the mouth of Copperas Creek Diversion channel to Bogus Island. The upper area in the chute by Blanchard Island had been highly recommended by local fishermen for fishing; however, netting here was unsatisfactory. Nets were set at various locations in the steamboat channel in the Blanchard Island locality. The channel sets were made in water of 15-foot depth over sand bottom. There are extensive drainage districts on both sides of the river here, largely confining the river to its channel; however, in the area of Bogus Island on the Iowa side there are some stretches of backwater.

The mussel fishery of the Mississippi River is not within the scope of this paper;

however, it is of interest in relation to fish habitat to mention that no activity in the shell or mussel fishery was observed below the Muscatine area. At Muscatine, on days when favorable weather prevailed, there were usually 12 to 15 shell-fishing boats in view from the Muscatine waterfront. Some activity of shell fishermen was noted upstream as far as Clinton, Iowa. In this stretch of water there is some clean gravel bottom, which apparently furnishes a more suitable habitat for mussels of economic importance than does the lower section of the river visited during the fishery investigation.

24.—Fairport, Iowa (D-MR section, June 2–13, 1946). This station and the one at Bellevue were the only sampling sites in the lower reaches of the pools. As discussed earlier the lower part of a navigation pool differs from the upper by having slower current and a more extensive silt bottom. The netting at the Fairport station was done in the region of Hershey Slough and Wyoming Slough near the mouth of Sweetheart Creek. This site was 2 to 3 miles above Lock and Dam No. 16 and 3 miles below Fairport. The nets were set in water ranging from 3 to 15 feet in depth.

25.—Andalusia, Illinois (D-MR section, April 1–7, June 18–26, and September 15–24, 1946). The Andalusia area, in the middle part of Pool No. 16, was used as the key station in 1946. This station was centrally located in relation to the other stations, and the habitats of the Andalusia area were more like those of the other 1946 stations than the Grafton habitats were like the habitats of the other 1944 stations. The general conditions at Andalusia were typical of those of the canalized section of the river.

River stages at Andalusia were high during April and June as compared with those during September. Netting during the three periods was done in the river channel, sloughs, and chutes near islands numbered 317, 318, and 319. The bottom in the sloughs and chutes was mud and the channel bottom was sand and sand-mud. The bottom of the channel and the current were satisfactory for trammel-net-float fishing. The sloughs here were confined to the Illinois side and the channel followed the Iowa side.

26.—Pleasant Valley, Iowa (D-MR section, June 28–July 9, 1946). This station, located in the upper part of Pool No. 15, was immediately below Pleasant Valley and 1 to 2 miles below Lock and Dam No. 14. Netting was done in the channel and chutes adjacent to Spencer Island and Campbell Island. The current in the channel was rather strong and the bottom was sand. In the chutes the bottom was of mud and some sand, and the depth of water there varied from 3.5 to 12.0 feet.

Above Lock and Dam No. 14 is the location of the former Le Claire Rapids. The site of these once great rapids is now merely a part of Pool No. 14. The elimination of the Le Claire and Keokuk rapids has greatly improved navigation on the river; however, its effect on spawning grounds for such fish as the blue sucker is not measurable.

27.—Cordova, Illinois (D-MR section, July 11–22, 1946). This station, in the middle reach of Pool No. 14, was located one-half mile to 2 miles above Cordova and 3 miles below the mouth of one of the noted smallmouth bass streams in Iowa, the Wapsipinicon River. Here the Mississippi channel hugged the Illinois shore. On the Iowa side were many bays and sloughs formed by the impoundment. These were dotted with dead trees killed by high water, 2 to 6 feet deep there, with no current; the bottoms were of mud. Netting operations were carried on in an area back as far as 1 mile from the river channel and also in the river channel and sloughs above the mouth of Pinneo Creek.

28.—Fulton, Illinois (D-MR section, July 24–August 4, 1946). The netting at this station was carried on above Fulton and Clinton, on opposite banks of the Mississippi, and was confined within the upper 1.5 miles of Pool No. 14. The current in the channel was swift; the bottom was principally sand but with some rock. The backwater areas were numerous and they were rather shallow, varying in depth from 3 to 4 feet. Sampling was done in the backwaters, the channel, and its adjoining sloughs and chutes.

29.—Sabula, Iowa (D-MR section, August 6–17, 1946). The Sabula station was located in the middle reach of Pool No. 13. The river here was too sluggish to float a trammel net efficiently. The bottom in the channel was mud and sand. Much of the netting at this station was done in the backwaters, a levee borrow pit, and chutes. Stumps, both submerged and protruding,

were numerous in the backwaters. Netting was done also in Savanna Slough. A period of netting was conducted near Savanna, above Sabula, in a levee borrow pit adjacent to the river. Water in this pit was about 4 feet in depth and the bottom was mud. Width of the water area varied from 50 to 75 feet. Following the netting period in this borrow pit a census was made of the fish population, August 13–17, by blocking off the outlet to the river with a seine and introducing a fish poison. The area covered in the poison census was 2.16 acres. Near this location, part of another levee borrow pit was treated with poison. This part was the blind end of the pit, 100 or more feet in width, and 0.964 acre in area. Fish had access to the river from this pit.

30.—Bellevue, Iowa (D-MR section, August 19–30, 1946). This station was located in the lower part of Pool No. 12. As at other stations in the lower parts of navigation pools, the current here was sluggish and the bottom predominantly silt or mud. Netting in the channel was done in the vicinity of islands numbered 242 and 243, 3 to 4 miles above Bellevue and Lock and Dam No. 12. Some nets were set in the channel in water as deep as 15 feet.

In the lower part of this pool, aquatic vegetation was quite abundant. Much of the shore line of the islands was covered with heavy growths of arrowhead, *Sagittaria* sp. Some of the backwater areas had 1- to 2-acre beds of American lotus, *Nelumbo lutea* (Willd.) Pers. The numerous shallow sloughs and small lakes in the area were covered with abundant growths of rice cutgrass, *Leersia oryzoides* (L.) Sw. Some netting was done in the backwaters near the mouth of Small Pox Creek.

31.—Dubuque, Iowa (D-MR section, September 1–12, 1946). This was the uppermost station in that part of the Mississippi River studied in the Caruthersville-Dubuque survey. It was at the northern boundary of the state of Illinois. The river above this station up to Prescott, Wisconsin, was investigated by the states bordering the upper section of the upper Mississippi River, namely, Iowa, Minnesota, and Wisconsin.

The Dubuque station was in the upper part of Pool No. 12, fig. 5, located 1 to 4 miles below the city of Dubuque. Netting was done in the backwaters adjoining Lake Frentress, in chutes, and in channels in the area. The netting sites in backwaters and lakes were in shallow water ranging from 3.5 to 5.0 feet in depth and having mud bottoms. The chutes sampled had sand and mud bottoms, and the channel had a sand bottom. The current in the channel was only moderately swift. Above the sampling area to Lock and Dam No. 11 the river is rather closely confined. The bluffs on both sides of the river in this region are quite high and steep. This section of Illinois and Iowa is referred to by geologists as unglaciated or driftless area.

Appendix B, Table 1.—Number, weight, and per cent of total weight by station of various River survey in 1944 between Caruthers-

Species	Caruthersville, Mo. April 6-12, 1944			Tiptonville, Tenn. April 15-May 10, 1944		
	Number	Weight, Pounds	Per Cent of Weight	Number	Weight, Pounds	Per Cent of Weight
COMMERCIAL FISHES						
*Scaphirhynchus album**	0	—	—	0	—	—
Shovelnose sturgeon	0	—	—	0	—	—
Paddlefish	0	—	—	7	2.65	0.51
American eel	0	—	—	0	—	—
Blue sucker	0	—	—	0	—	—
Bigmouth buffalo	2	1 68	0 53	27	30.62	5.85
Black buffalo	0	—	—	7	2.58	0 49
Smallmouth buffalo	6	2.90	0 91	23	32.24	6 16
Carpsuckers†	6	3.86	1 21	28	25.63	4 89
Northern redhorse	0	—	—	0	—	—
Carp	37	60 10	18 91	63	127.65	24 38
Channel catfish	5	1 68	0 53	81	23 30	4.45
Blue catfish	16	4 19	1.32	92	39.83	7 61
Yellow bullhead	0	—	—	3	2.50	0 48
Brown bullhead	0	—	—	1	0 54	0.10
Black bullhead	48	21 42	6.74	94	72.30	13 81
Flathead catfish	14	14 74	4 64	5	12.93	2 47
Freshwater drum	8	1 78	0.56	24	16.11	3 08
Subtotal	*142*	*112 35*	*35.35*	*455*	*388 88*	*74 28*
SPORT FISHES						
Grass pickerel	0	—	—	0	—	—
Yellow pikeperch	0	—	—	0	—	—
Sauger	1	0 58	0 18	3	2 21	0 42
Spotted black bass	2	1.21	0 38	0	—	—
Largemouth black bass	4	2 91	0 92	1	1.51	0 29
Green sunfish	0	—	—	17	1.98	0.38
Bluegill	8	1 40	0 44	9	1.54	0 29
Warmouth	4	0 89	0.28	10	2 90	0 55
Flier	0	—	—	0	—	—
White crappie	63	17.41	5 48	23	6 97	1.33
Black crappie	57	8 87	2.79	16	3 99	0 76
White bass	6	2.66	0 84	2	0.25	0 05
Yellow bass	1	0.16	0.05	1	0.32	0 06
Subtotal	*146*	*36 09*	*11.36*	*82*	*21.67*	*4 13*
PREDATORY FISHES						
Longnose gar	1	0.20	0 06	14	60 99	11 65
Shortnose gar	69	124 09	39 05	17	28 47	5 43
Alligator gar	0	—	—	0	—	—
Bowfin	0	—	—	0	—	—
Subtotal	*70*	*124 29*	*39.11*	*31*	*89.46*	*17 08*
FORAGE FISHES						
Mooneye and goldeye	4	1.37	0 43	5	1.51	0.29
Skipjack	3	1 59	0.50	3	1.19	0.23
Gizzard shad	93	42 12	13.25	68	20.89	3 99
Golden shiner	0	—	—	0	—	—
Subtotal	*100*	*45.08*	*14.18*	*76*	*23.59*	*4.51*
Total	*458*	*317 81*	*100.00*	*644*	*523.60*	*100.00*

* None taken in test nets but one procured from angler at time of survey.
† *Carpiodes* spp.

species of fish (except those in minnow seine collections) taken during the Mississippi ville, Missouri, and Warsaw, Illinois.

CAIRO, ILL. MAY 18–24, 1944			CAPE GIRARDEAU, MO. MAY 26–31, 1944			GRAND TOWER, ILL. JUNE 2–9, 1944			CHESTER, ILL. JUNE 11–15, 1944		
Number	Weight, Pounds	Per Cent of Weight	Number	Weight, Pounds	Per Cent of Weight	Number	Weight, Pounds	Per Cent of Weight	Number	Weight, Pounds	Per Cent of Weight
0	—	—	0	—	—	0	—	—	0	—	—
0	—	—	0	—	—	0	—	—	0	—	—
14	17 89	2 34	0	—	—	1	1 10	0 12	2	2 98	0.51
4	5.45	0.71	0	—	—	0	—	—	0	—	—
0	—	—	0	—	—	0	—	—	0	—	—
8	34.08	4 47	2	10 57	1 40	5	18 57	2.00	1	3 17	0 54
1	1 87	0 25	7	60.76	8 07	7	34.39	3.70	0	—	—
22	38.20	5 01	0	—	—	14	31 55	3 39	2	0.48	0 08
40	53 18	6 97	7	13.22	1.76	77	123 18	13.23	7	4 07	0.69
0	—	—	0	—	—	0	—	—	0	—	—
60	132 72	17 39	82	247 08	32 81	162	299 65	32 20	140	271.74	46.43
12	10 18	1 33	4	6 92	0 92	6	6.51	0.70	2	2 32	0 40
20	11 18	1 47	20	19 31	2 56	26	11 11	1 19	10	19 66	3.36
1	1 02	0 13	0	—	—	0	—	—	0	—	—
0	—	—	0	—	—	0	—	—	0	—	—
81	69 42	9 10	2	1 80	0 24	32	18 40	1 98	2	1.26	0 22
33	59.00	7 73	88	327 67	43 50	26	65 46	7 03	88	186 06	31 79
114	46 68	6 12	17	17 55	2 33	30	23 68	2 54	10	7 32	1 25
410	*480 87*	*63 02*	*229*	*704 88*	*93 59*	*386*	*633 60*	*68 08*	*264*	*499 06*	*85 27*
0	—	—	0	—	—	0	—	—	0	—	—
0	—	—	0	—	—	0	—	—	0	—	—
8	5 16	0 68	0	—	—	5	3 14	0 34	2	1 60	0 27
0	—	—	0	—	—	0	—	—	0	—	—
0	—	—	0	—	—	2	1 23	0 13	2	0.95	0.16
0	—	—	0	—	—	0	—	—	0	—	—
1	0 35	0 05	0	—	—	10	2 23	0 24	3	0 65	0.11
0	—	—	0	—	—	1	0 22	0 02	0	—	—
1	0 10	0 01	0	—	—	0	—	—	0	—	—
7	1 86	0 24	0	—	—	9	2 70	0 29	4	1 09	0.19
5	1 49	0.20	0	—	—	6	1 59	0 17	7	2 29	0 39
12	5 34	0 70	0	—	—	0	—	—	1	0.40	0 07
0	—	—	0	—	—	0	—	—	0	—	—
34	*14 30*	*1 88*	*0*	—	—	*33*	*11.11*	*1 19*	*19*	*6.98*	*1.19*
5	10 32	1 35	3	10 56	1.40	8	12 08	1.30	3	7.55	1 29
33	31 38	4 11	60	35.02	4 65	268	147 39	15.84	62	59 76	10 21
80	182 29	23 89	1	1.66	0 22	2	58 86	6.32	1	2 38	0 41
1	1.65	0 22	1	1.05	0 14	23	53 49	5 75	2	7 17	1 22
119	*225 64*	*29.57*	*65*	*48.29*	*6 41*	*301*	*271 82*	*29.21*	*68*	*76 86*	*13.13*
6	2.72	0.36	0	—	—	4	1 26	0 14	2	0.76	0 13
5	3 16	0.41	0	—	—	0	—	—	0	—	—
71	36 34	4.76	0	—	—	17	12.88	1 38	4	1.64	0.28
0	—	—	0	—	—	0	—	—	0	—	—
82	*42.22*	*5 53*	*0*	—	—	*21*	*14.14*	*1.52*	*6*	*2.40*	*0.41*
645	*763.03*	*100 00*	*294*	*753.17*	*100.00*	*741*	*930 67*	*100 00*	*357*	*585 30*	*100 00*

Appendix B, Table 1.—

Species	Ste. Genevieve, Mo. June 18–24, 1944			Crystal City, Mo. June 25–30, 1944		
	Number	Weight, Pounds	Per Cent of Weight	Number	Weight, Pounds	Per Cent of Weight
COMMERCIAL FISHES						
*Scaphirhynchus album**	0	—	—	0	—	—
Shovelnose sturgeon	0	—	—	0	—	—
Paddlefish	0	—	—	0	—	—
American eel	0	—	—	3	7.95	1 01
Blue sucker	0	—	—	0	—	—
Bigmouth buffalo	0	—	—	0	—	—
Black buffalo	1	5 94	0.56	0	—	—
Smallmouth buffalo	14	29 98	2.81	21	14 52	1 84
Carpsucker†	89	148 91	13 97	41	43 44	5 50
Northern redhorse	0	—	—	7	4 20	0.53
Carp	320	616 70	57.87	210	494 07	62 60
Channel catfish	27	49 96	4.69	6	11.62	1 47
Blue catfish	8	3 72	0 35	14	13 48	1.71
Yellow bullhead	0	—	—	0	—	—
Brown bullhead	0	—	—	0	—	—
Black bullhead	0	—	—	3	1.53	0 19
Flathead catfish	28	106 11	9 96	38	106 81	13 53
Freshwater drum	45	39 00	3 66	34	26 79	3 40
Subtotal	*532*	*1,000 32*	*93 87*	*377*	*724 41*	*91 78*
SPORT FISHES						
Grass pickerel	0	—	—	0	—	—
Yellow pikeperch	0	—	—	0	—	—
Sauger	2	1 66	0 16	0	—	—
Spotted black bass	0	—	—	0	—	—
Largemouth black bass	0	—	—	1	0 77	0 10
Green sunfish	0	—	—	1	0 32	0 04
Bluegill	0	—	—	4	0 73	0 09
Warmouth	0	—	—	0	—	—
Flier	0	—	—	0	—	—
White crappie	0	—	—	10	2 57	0 33
Black crappie	0	—	—	28	9 13	1 16
White bass	0	—	—	3	1 59	0 20
Yellow bass	0	—	—	0	—	—
Subtotal	*2*	*1 66*	*0 16*	*47*	*15 11*	*1 92*
PREDATORY FISHES						
Longnose gar	7	19 65	1 84	6	20 79	2 63
Shortnose gar	49	42.03	3.94	20	17 07	2 16
Alligator gar	0	—	—	0	—	—
Bowfin	0	—	—	0	—	—
Subtotal	*56*	*61.68*	*5.78*	*26*	*37 86*	*4.79*
FORAGE FISHES						
Mooneye and goldeye	2	1.22	0.11	20	8.93	1.13
Skipjack	0	—	—	0	—	—
Gizzard shad	2	0.84	0.08	9	3 00	0.38
Golden shiner	0	—	—	0	—	—
Subtotal	*4*	*2 06*	*0 19*	*29*	*11.93*	*1.51*
Total	*594*	*1,065.72*	*100 00*	*479*	*789.31*	*100.00*

* None taken in test nets but one procured from angler at time of survey.
† *Carpiodes* spp.

Continued.

Cliff Cave, Mo. July 2–8, 1944			Below Mouth of Missouri River July 10–15, 1944			Above Mouth of Missouri River July 10–15, 1944			Grafton, Ill. March 22–30, 1944		
Number	Weight, Pounds	Per Cent of Weight	Number	Weight, Pounds	Per Cent of Weight	Number	Weight, Pounds	Per Cent of Weight	Number	Weight, Pounds	Per Cent of Weight
0	—	—	0	—	—	1	0.12	0.01	0	—	—
0	—	—	0	—	—	0	—	—	0	—	—
0	—	—	0	—	—	0	—	—	1	0.85	0.11
3	6.50	0.81	0	—	—	3	7.40	0.87	0	—	—
0	—	—	0	—	—	0	—	—	0	—	—
3	10.42	1.29	0	—	—	7	19.58	2.30	13	19.13	2.57
7	20.27	2.51	0	—	—	0	—	—	9	31.55	4.23
25	79.38	9.82	0	—	—	6	2.19	0.26	21	13.29	1.78
33	52.57	6.50	6	10.32	3.70	17	16.35	1.92	20	12.44	1.67
0	—	—	0	—	—	0	—	—	0	—	—
183	470.87	58.25	54	133.79	48.00	309	372.35	43.83	51	88.08	11.81
4	5.44	0.67	1	2.40	0.86	23	28.75	3.39	22	4.09	0.55
19	12.85	1.59	6	0.52	0.19	14	5.23	0.62	8	5.96	0.80
0	—	—	0	—	—	0	—	—	1	0.50	0.07
0	—	—	0	—	—	0	—	—	2	0.69	0.09
0	—	—	0	—	—	0	—	—	25	14.49	1.94
25	88.91	11.00	27	101.75	36.50	44	81.92	9.64	0	—	—
41	30.82	3.81	25	14.23	5.11	227	81.33	9.58	73	17.55	2.35
343	*778.03*	*96.25*	*119*	*263.01*	*94.36*	*651*	*615.22*	*72.42*	*246*	*208.62*	*27.97*
0	—	—	0	—	—	0	—	—	2	1.05	0.14
0	—	—	0	—	—	0	—	—	0	—	—
0	—	—	0	—	—	1	1.04	0.12	0	—	—
0	—	—	0	—	—	0	—	—	0	—	—
0	—	—	0	—	—	11	16.66	1.96	30	47.20	6.33
0	—	—	0	—	—	0	—	—	0	—	—
0	—	—	4	0.64	0.23	31	8.72	1.03	288	65.79	8.82
0	—	—	0	—	—	0	—	—	36	10.81	1.45
0	—	—	0	—	—	0	—	—	0	—	—
0	—	—	3	1.01	0.36	4	1.14	0.13	74	35.23	4.72
0	—	—	4	1.87	0.67	303	116.27	13.69	331	146.17	19.60
0	—	—	0	—	—	1	0.56	0.07	3	1.69	0.23
0	—	—	0	—	—	0	—	—	1	0.38	0.05
0	—	—	*11*	*3.52*	*1.26*	*351*	*144.39*	*17.00*	*765*	*308.32*	*41.34*
4	9.64	1.19	0	—	—	7	7.34	0.87	5	12.23	1.64
21	20.72	2.56	3	2.76	0.99	100	71.45	8.41	76	90.09	12.08
0	—	—	0	—	—	0	—	—	0	—	—
0	—	—	2	9.46	3.39	2	3.94	0.46	8	28.18	3.78
25	*30.36*	*3.75*	*5*	*12.22*	*4.38*	*109*	*82.73*	*9.74*	*89*	*130.50*	*17.50*
0	—	—	0	—	—	6	3.70	0.44	7	1.86	0.25
0	—	—	0	—	—	0	—	—	0	—	—
0	—	—	0	—	—	5	3.42	0.40	134	95.81	12.85
0	—	—	0	—	—	0	—	—	2	0.67	0.09
0	—	—	*0*	—	—	*11*	*7.12*	*0.84*	*143*	*98.34*	*13.10*
368	*808.39*	*100.00*	*135*	*278.75*	*100.00*	*1,122*	*849.46*	*100.00*	*1,243*	*745.78*	*100.00*

Appendix B, Table 1.—

Species	Grafton, Ill. July 17–25, 1944			Grafton, Ill. Sept. 22–27, 1944		
	Number	Weight, Pounds	Per Cent of Weight	Number	Weight, Pounds	Per Cent of Weight
Commercial Fishes						
*Scaphirhynchus album**	0	—	—	0	—	—
Shovelnose sturgeon	0	—	—	0	—	—
Paddlefish	0	—	—	0	—	—
American eel	3	7.28	1.15	5	11.51	3.41
Blue sucker	0	—	—	0	—	—
Bigmouth buffalo	12	19.11	3.02	0	—	—
Black buffalo	4	28.04	4.43	1	2.80	0.83
Smallmouth buffalo	39	18.24	2.88	22	15.21	4.51
Carpsuckers†	35	26.74	4.23	14	10.43	3.09
Northern redhorse	0	—	—	3	3.84	1.14
Carp	46	82.21	12.99	18	41.00	12.15
Channel catfish	5	7.42	1.17	11	4 02	1 19
Blue catfish	2	0.27	0.04	2	1.33	0.39
Yellow bullhead	6	2.93	0.46	13	7.71	2.28
Brown bullhead	3	3 45	0 55	0	—	—
Black bullhead	14	7.64	1.21	0	—	—
Flathead catfish	14	23 46	3.71	6	12.56	3 72
Freshwater drum	33	16.13	2.55	25	11.28	3 34
Subtotal	*216*	*242.92*	*38.39*	*120*	*121 69*	*36 05*
Sport Fishes						
Grass pickerel	0	—	—	0	—	—
Yellow pikeperch	0	—	—	0	—	—
Sauger	1	1 36	0 21	2	2 56	0.76
Spotted black bass	0	—	—	0	—	—
Largemouth black bass	36	34 03	5.38	28	25.83	7 65
Green sunfish	0	—	—	0	—	—
Bluegill	132	30.81	4.87	17	3.20	0.95
Warmouth	13	3.89	0.62	3	1.00	0 30
Flier	0	—	—	0	—	—
White crappie	74	16.84	2 66	58	16 00	4.74
Black crappie	353	113.73	17.97	185	80.13	23.74
White bass	32	16.71	2.64	30	16.93	5.02
Yellow bass	1	0.45	0.07	1	0.23	0.07
Subtotal	*642*	*217.82*	*34.42*	*324*	*145.88*	*43.23*
Predatory Fishes						
Longnose gar	13	30.42	4.81	1	2.68	0.79
Shortnose gar	43	43.92	6 94	4	4.30	1.27
Alligator gar	1	4 10	0 65	0	—	—
Bowfin	12	29.00	4.58	8	29 11	8.62
Subtotal	*69*	*107.44*	*16 98*	*13*	*36 09*	*10 68*
Forage Fishes						
Mooneye and goldeye	6	6.14	0.97	3	2.91	0.86
Skipjack	0	—	—	0	—	—
Gizzard shad	101	58.45	9.24	94	30.99	9.18
Golden shiner	0	—	—	0	—	—
Subtotal	*107*	*64.59*	*10.21*	*97*	*33.90*	*10.04*
Total	*1,034*	*632.77*	*100.00*	*554*	*337.56*	*100.00*

* None taken in test nets but one procured from angler at time of survey.
† *Carpiodes* spp.

Continued.

WINFIELD, MO. JULY 27–AUG. 2, 1944			HAMBURG, ILL. AUG. 3–9, 1944			LOUISIANA, MO. AUG. 12–17, 1944			CINCINNATI LANDING, ILL. AUG. 19–23, 1944		
Number	Weight, Pounds	Per Cent of Weight	Number	Weight, Pounds	Per Cent of Weight	Number	Weight, Pounds	Per Cent of Weight	Number	Weight, Pounds	Per Cent of Weight
0	—	—	0	—	—	0	—	—	0	—	—
0	—	—	0	—	—	0	—	—	0	—	—
7	4 96	0 57	1	0.22	0 04	0	—	—	0	—	—
0	—	—	2	5.37	1.01	0	—	—	3	4 98	1.43
0	—	—	0	—	—	0	—	—	1	2 80	0.80
7	17 60	2 03	2	5.29	0 99	3	6 64	1.99	5	10 23	2.94
3	8 79	1 01	3	10.74	2 01	1	2.26	0.68	2	3.34	0.96
57	47 72	5 51	24	28 26	5 29	23	15 81	4 73	30	21.42	6.15
11	8 04	0 93	36	34 29	6 42	22	18 36	5 49	8	7 64	2.19
0	—	—	1	1.85	0 35	0	—	—	3	6.02	1.73
79	118 76	13.71	55	98 56	18 45	33	75 25	22 50	45	104.04	29.88
24	27 36	3 16	34	33.89	6 35	18	20 81	6.22	13	9 39	2.70
24	16 23	1.87	3	2.48	0 46	9	1 64	0 49	8	3 62	1.04
1	0 16	0 02	2	2 06	0 39	0	—	—	0	—	—
0	—	—	0	—	—	0	—	—	0	—	—
5	3 72	0 43	0	—	—	0	—	—	0	—	—
39	67 16	7 75	15	40 17	7.52	19	36 39	10 88	33	106 49	30 58
79	48 69	5 62	34	28 37	5 31	98	61 67	18.44	52	32 77	9 41
336	*369 19*	*42 61*	*212*	*291 55*	*54 59*	*226*	*238 83*	*71 42*	*203*	*312 74*	*89 81*
0	—	—	0	—	—	0	—	—	0	—	—
1	1 43	0 17	0	—	—	0	—	—	0	—	—
2	1 64	0 19	0	—	—	3	3 38	1.01	7	6 59	1.89
0	—	—	0	—	—	0	—	—	0	—	—
10	10 23	1 18	5	5 53	1 03	0	—	—	0	—	—
0	—	—	0	—	—	0	—	—	0	—	—
28	5 76	0 66	42	9 40	1 76	0	—	—	0	—	—
0	—	—	0	—	—	0	—	—	0	—	—
0	—	—	0	—	—	0	—	—	0	—	—
254	62.21	7.18	236	61 79	11 57	19	7 40	2 21	1	0.45	0.13
70	20 52	2.37	77	25.84	4.84	11	3 80	1 14	6	2.01	0.58
23	16.50	1 90	26	12 89	2 41	0	—	—	3	6 91	1.98
1	0.34	0 04	0	—	—	0	—	—	0	—	—
389	*118 63*	*13 69*	*386*	*115 45*	*21 61*	*33*	*14.58*	*4 36*	*17*	*15.96*	*4.58*
18	50 47	5 83	4	8 91	1.67	9	28 65	8 57	2	3.34	0 96
136	121.50	14 02	71	60.04	11.24	22	24 13	7.22	6	8 42	2 42
0	—	—	0	—	—	0	—	—	0	—	—
41	128.05	14 78	7	25 42	4 76	2	5 43	1.62	0	—	—
195	*300 02*	*34.63*	*82*	*94 37*	*17 67*	*33*	*58.21*	*17.41*	*8*	*11.76*	*3 38*
5	2.17	0.25	1	0.17	0.03	1	0 55	0.16	0	—	—
0	—	—	0	—	—	0	—	—	0	—	—
142	76.43	8.82	67	32.57	6 10	44	22.23	6.65	18	7.78	2 23
0	—	—	0	—	—	0	—	—	0	—	—
147	*78 60*	*9.07*	*68*	*32.74*	*6.13*	*45*	*22.78*	*6 81*	*18*	*7.78*	*2.23*
1,067	*866.44*	*100.00*	*748*	*534.11*	*100.00*	*337*	*334.40*	*100.00*	*246*	*348.24*	*100 00*

Appendix B, Table 1.—

Species	Hannibal, Mo. Aug. 25–30, 1944 Number	Weight, Pounds	Per Cent of Weight	Quincy, Ill. Sept. 2–6, 1944 Number	Weight, Pounds	Per Cent of Weight
COMMERCIAL FISHES						
*Scaphirhynchus album**	0	—	—	0	—	—
Shovelnose sturgeon	0	—	—	3	4 78	0.40
Paddlefish	0	—	—	25	104.70	8 69
American eel	6	14 26	3.18	2	3 25	0 27
Blue sucker	0	—	—	0	—	—
Bigmouth buffalo	2	6 85	1 53	6	12 24	1 01
Black buffalo	2	3 25	0 72	2	3.72	0 31
Smallmouth buffalo	6	15 98	3 57	31	26.26	2 18
Carp suckers†	30	25 52	5 70	120	105 46	8 75
Northern redhorse	1	1 27	0 28	‡1	1 18	0.10
Carp	75	178.52	39 84	137	345 79	28 70
Channel catfish	18	9 73	2 17	126	67 74	5 62
Blue catfish	1	0 31	0 07	7	1 53	0 13
Yellow bullhead	0	—	—	0	—	—
Brown bullhead	0	—	—	0	—	—
Black bullhead	0	—	—	2	1.97	0 16
Flathead catfish	21	88 97	19 86	24	83 51	6 93
Freshwater drum	45	36 54	8 15	36	25 33	2 10
Subtotal	*207*	*381 20*	*85 07*	*522*	*787.46*	*65 35*
SPORT FISHES						
Grass pickerel	0	—	—	0	—	—
Yellow pikeperch	0	—	—	1	4 00	0.33
Sauger	4	4 69	1 05	4	5 59	0.46
Spotted black bass	0	—	—	0	—	—
Largemouth black bass	0	—	—	0	—	—
Green sunfish	0	—	—	0	—	—
Bluegill	0	—	—	6	1 02	0 08
Warmouth	0	—	—	0	—	—
Flier	0	—	—	0	—	—
White crappie	41	7 88	1 76	61	27 19	2 26
Black crappie	11	3 56	0 79	26	12 02	1.00
White bass	2	0 80	0.18	11	6 72	0.56
Yellow bass	0	—	—	0	—	—
Subtotal	*58*	*16 93*	*3.78*	*109*	*56 54*	*4.69*
PREDATORY FISHES						
Longnose gar	4	8 73	1 95	38	65.81	5.46
Shortnose gar	25	28.14	6 28	209	249.16	20 68
Alligator gar	0	—	—	0	—	—
Bowfin	0	—	—	1	2.71	0.22
Subtotal	*29*	*36 87*	*8 23*	*248*	*317.68*	*26.36*
FORAGE FISHES						
Mooneye and goldeye	9	4 48	1.00	6	3 27	0.27
Skipjack	0	—	—	0	—	—
Gizzard shad	28	8.61	1 92	97	40.06	3.33
Golden shiner	0	—	—	0	—	—
Subtotal	*37*	*13 09*	*2.92*	*103*	*43.33*	*3.60*
Total	*331*	*448 09*	*100.00*	*982*	*1,205.01*	*100 00*

* None taken in test nets but one procured from angler at time of survey.
† *Carpiodes* spp.
‡ Undetermined species of redhorse (*Moxostoma*).

Concluded.

Canton, Mo. Sept. 8–13, 1944			Warsaw, Ill. Sept. 14–19, 1944			Total Number of Fish Caught	Total Weight in Pounds	Per Cent of Total Weight
Number	Weight, Pounds	Per Cent of Weight	Number	Weight, Pounds	Per Cent of Weight			
0	—	—	0	—	—	1	0.12	0 00
0	—	—	0	—	—	3	4.78	0.03
18	29.92	5 71	0	—	—	76	165.27	1.14
2	3.62	0 69	1	2.67	0 32	37	80.24	0.55
2	3.70	0.71	0	—	—	3	6.50	0.05
1	3.03	0 56	3	6 04	0 72	109	234 85	1.62
0	—	—	1	5.37	0.64	58	225.67	1.56
23	30 25	5 77	59	124 05	14.86	468	587.93	4 06
81	78.97	15 06	211	219 46	26.29	939	1,042 08	7.20
1	1 84	0 35	3	4 69	0.56	20	24 89	0.17
52	139 11	26.54	114	254 47	30.48	2,325	4,752.51	32 83
10	8 73	1.67	16	10 21	1.22	468	352 47	2.43
1	0.19	0 04	1	3 68	0 44	311	178 32	1.23
1	0 44	0 08	0	—	—	28	17.32	0.12
0	—	—	0	—	—	6	4.68	0 03
1	1.45	0 28	1	0.46	0.06	310	215.86	1.49
19	38 57	7 36	11	60 61	7 26	617	1,709.25	11.81
30	24 12	4 60	36	32 80	3 93	1,116	640.54	4.43
242	*363 94*	*69 42*	*457*	*724 51*	*86.78*	*6,895*	*10,243 28*	*70 75*
0	—	—	0	—	—	2	1.05	0.01
0	—	—	0	—	—	2	5.43	0.04
0	—	—	22	21 35	2 56	67	62.55	0.43
0	—	—	0	—	—	2	1.21	0 01
2	1 32	0 25	1	1 08	0 13	133	149.25	1 03
0	—	—	0	—	—	18	2 30	0 02
12	2 21	0.42	0	—	—	595	134.45	0 93
0	—	—	0	—	—	67	19 71	0.14
0	—	—	0	—	—	1	0 10	0.00
53	25 91	4 94	4	1 90	0.23	998	297.55	2.06
16	10 20	1.95	3	1.42	0 17	1,515	564 90	3.90
56	15 85	3 02	6	3 93	0 47	217	109.73	0.76
0	—	—	0	—	—	6	1 88	0.01
139	*55.49*	*10 58*	*36*	*29.68*	*3 56*	*3,623*	*1,350.11*	*9.34*
26	14 27	2.72	16	18 70	2.24	194	403.33	2 79
76	57 39	10 95	41	39.94	4.78	1,411	1,307 17	9 03
0	—	—	0	—	—	85	249.29	1.72
0	—	—	0	—	—	110	324 66	2.24
102	*71.66*	*13 67*	*57*	*58 64*	*7 02*	*1,800*	*2,284.45*	*15 78*
4	1.93	0 37	18	9 69	1 16	109	54.64	0 38
1	1.09	0.21	3	2 12	0.25	15	9.15	0.06
54	30 12	5.75	21	10.28	1 23	1,069	534.46	3.69
0	—	—	0	—	—	2	0.67	0 00
59	*33.14*	*6.33*	*42*	*22.09*	*2.64*	*1,195*	*598.92*	*4.13*
542	*524 23*	*100.00*	*592*	*834.92*	*100 00*	*13,513*	*14,476.76*	*100.00*

Appendix B, Table 2.—Number, weight, and per cent of total weight by station of various species of fish (except those in minnow seine collections) taken during the Mississippi River survey in 1946 between Burlington and Dubuque, Iowa.

Species	Burlington, Iowa April 10–22, 1946			Oquawka, Ill. April 24–May 5, 1946			New Boston, Ill. May 7–18, 1946			Muscatine, Iowa May 19–30, 1946			Fairport, Iowa June 2–13, 1946			Andalusia, Ill. April 1–7, 1946		
	Number	Weight, Pounds	Per Cent of Weight	Number	Weight, Pounds	Per Cent of Weight	Number	Weight, Pounds	Per Cent of Weight	Number	Weight, Pounds	Per Cent of Weight	Number	Weight, Pounds	Per Cent of Weight	Number	Weight, Pounds	Per Cent of Weight
COMMERCIAL FISHES																		
Shovelnose sturgeon	0	—	—	0	—	—	0	—	—	0	—	—	0	—	—	147	197.10	41.54
Mooneye	83	10.41	1.13	3	0.23	0.04	12	1.74	0.15	1	0.18	0.01	1	0.33	0.03	50	10.24	2.16
Goldeye	28	10.44	1.13	0	—	—	1	0.34	0.03	0	—	—	5	5.76	0.62	11	8.80	1.85
American eel	0	—	—	0	—	—	1	3.25	0.30	2	4.39	0.31	2	3.34	0.36	0	—	—
Blue sucker	0	—	—	0	—	—	0	—	—	0	—	—	0	—	—	0	—	—
Bigmouth buffalo	87	237.73	25.78	22	59.73	10.86	7	26.50	2.41	11	11.87	0.84	12	37.12	4.00	6	14.09	2.97
Black buffalo	3	22.52	2.44	2	6.58	1.20	2	9.42	0.86	0	—	—	0	—	—	1	2.08	0.44
Smallmouth buffalo	175	76.90	8.34	42	54.91	9.99	12	11.71	1.07	27	49.27	3.46	19	31.00	3.34	32	63.61	13.41
Carpsuckers*	139	144.21	15.64	109	142.76	25.96	181	238.05	21.67	211	298.66	21.00	159	247.26	26.62	38	33.99	7.16
White sucker	1	0.68	0.07	0	—	—	0	—	—	0	—	—	0	—	—	0	—	—
Spotted sucker	0	—	—	0	—	—	1	0.91	0.08	0	—	—	0	—	—	0	—	—
Silver redhorse	0	—	—	0	—	—	0	—	—	0	—	—	0	—	—	0	—	—
Northern redhorse	0	—	—	1	4.07	0.74	2	3.53	0.32	1	2.20	0.15	5	7.78	0.84	2	1.70	0.36
Carp	72	242.32	26.28	33	127.18	23.13	91	324.26	29.52	220	816.55	57.42	83	263.01	28.32	14	50.56	10.66
Channel catfish	189	41.33	4.48	14	7.80	1.42	55	16.28	1.48	78	21.23	1.49	103	57.22	6.16	104	25.79	5.43
Yellow bullhead	0	—	—	5	1.82	0.33	3	1.72	0.16	1	0.71	0.05	0	—	—	0	—	—
Black bullhead	10	1.67	0.18	6	3.50	0.64	5	2.88	0.26	1	0.50	0.04	0	—	—	7	1.75	0.37
Flathead catfish	3	1.62	0.18	3	1.11	0.20	8	30.96	2.82	4	4.43	0.31	29	180.52	19.44	1	2.45	0.52
Freshwater drum	164	52.51	5.69	13	7.97	1.45	19	5.22	0.48	64	75.24	5.29	15	18.42	1.98	8	10.48	2.21
Subtotal	*954*	*842.34*	*91.34*	*253*	*417.66*	*75.96*	*400*	*676.77*	*61.61*	*621*	*1,285.23*	*90.37*	*433*	*851.76*	*91.71*	*421*	*422.64*	*89.08*

SPORT FISHES																		
Pike	0	—	—	0	—	—	1	3.49	0.32	0	—	—	0	—	—	0	—	—
Yellow pikeperch	1	2.15	0.23	0	—	—	0	—	—	0	—	—	0	—	—	2	1.15	0.24
Sauger	0	—	—	0	—	—	0	—	—	3	1.58	0.11	3	3.58	0.38	3	2.23	0.47
Spotted black bass	0	—	—	0	—	—	0	—	—	0	—	—	0	—	—	0	—	—
Largemouth black bass	0	—	—	3	4.46	0.81	2	1.48	0.13	1	2.47	0.18	0	—	—	0	—	—
Green sunfish	0	—	—	1	0.14	0.02	0	—	—	1	0.11	0.01	0	—	—	0	—	—
Bluegill	10	2.91	0.32	20	4.23	0.77	34	7.27	0.66	31	8.30	0.58	0	—	—	1	0.24	0.05
Warmouth	0	—	—	4	1.57	0.29	1	0.50	0.05	3	1.05	0.07	0	—	—	1	0.11	0.02
White crappie	30	6.66	0.72	120	37.27	6.78	403	202.58	18.44	155	15.11	1.06	84	3.21	0.35	5	0.89	0.19
Black crappie	11	2.56	0.28	92	19.53	3.55	138	52.55	4.78	113	27.19	1.91	20	0.80	0.09	5	0.91	0.19
White bass	21	1.60	0.17	1	0.12	0.02	39	13.63	1.24	8	2.68	0.19	0	—	—	14	8.11	1.71
Yellow bass	6	0.67	0.07	2	0.38	0.07	217	67.22	6.12	0	—	—	0	—	—	0	—	—
Subtotal	*79*	*16.55*	*1.79*	*243*	*67.70*	*12.31*	*835*	*348.72*	*31.74*	*315*	*58.49*	*4.11*	*107*	*7.59*	*0.82*	*31*	*13.64*	*2.87*
PREDATORY FISHES																		
Longnose gar*	3	25.45	2.76	0	—	—	1	8.00	0.73	4	6.68	0.47	2	2.19	0.24	3	15.24	3.21
Shortnose gar	28	32.79	3.56	1	1.88	0.34	10	10.27	0.93	9	8.74	0.62	26	56.45	6.08	12	14.14	2.98
Bowfin	1	3.37	0.37	16	55.09	10.02	6	22.35	2.03	19	63.02	4.43	3	10.70	1.15	3	8.05	1.70
Subtotal	*32*	*61.61*	*6.69*	*17*	*56.97*	*10.36*	*17*	*40.62*	*3.69*	*32*	*78.44*	*5.52*	*51*	*69.34*	*7.47*	*18*	*37.43*	*7.89*
FORAGE FISHES																		
Gizzard shad	4	1.70	0.18	10	7.52	1.37	75	32.51	2.96	0	—	—	0	—	—	1	0.78	0.16
Total	*1,069*	*922.20*	*100.00*	*523*	*549.85*	*100.00*	*1,327*	*1098.62*	*100.00*	*968*	*1,422.16*	*100.00*	*591*	*928.69*	*100.00*	*471*	*474.49*	*100.00*

* *Carpiodes* spp.

Appendix B, Table 2.—Continued.

Species	Andalusia, Ill. June 18–26, 1946			Andalusia, Ill. Sept. 15–24, 1946			Pleasant Valley, Iowa June 28–July 9, 1946			Cordova, Ill. July 11–22, 1946			Fulton, Ill. July 24–Aug. 4, 1946			Sabula, Iowa Aug. 6–17, 1946		
	Number	Weight, Pounds	Per Cent of Weight	Number	Weight, Pounds	Per Cent of Weight	Number	Weight, Pounds	Per Cent of Weight	Number	Weight, Pounds	Per Cent of Weight	Number	Weight, Pounds	Per Cent of Weight	Number	Weight, Pounds	Per Cent of Weight
Commercial Fishes																		
Shovelnose sturgeon	56	81.22	5.46	77	82.44	5.01	0	—	—	0	—	—	0	—	—	0	—	—
Mooneye	4	1.43	0.10	8	1.78	0.11	2	0.35	0.04	9	1.69	0.22	1	0.30	0.02	0	—	—
Goldeye	2	0.51	0.03	23	3.77	0.23	5	2.96	0.35	6	0.73	0.09	3	0.94	0.07	0	—	—
American eel	3	8.21	0.55	1	2.68	0.16	1	1.75	0.21	1	3.83	0.49	1	3.00	0.22	1	5.25	0.80
Blue sucker	0	—	—	3	9.09	0.55	1	3.54	0.41	1	3.58	0.46	0	—	—	0	—	—
Bigmouth buffalo	45	112.19	7.54	6	18.84	1.15	18	50.07	5.86	7	23.21	2.99	12	15.22	1.09	10	43.14	6.55
Black buffalo	2	15.05	1.01	2	7.95	0.48	3	10.31	1.21	2	14.11	1.82	3	3.43	0.25	4	14.40	2.19
Smallmouth buffalo	49	80.27	5.39	33	44.11	2.68	40	66.64	7.80	28	18.64	2.40	11	4.80	0.34	0	—	—
Carpsuckers*	291	407.04	27.36	122	144.11	8.76	124	154.55	18.10	36	65.76	8.47	44	45.22	3.25	16	21.70	3.30
White sucker	0	—	—	0	—	—	3	5.41	0.63	0	—	—	0	—	—	0	—	—
Spotted sucker	0	—	—	0	—	—	0	—	—	0	—	—	0	—	—	0	—	—
Silver redhorse	0	—	—	1	2.57	0.16	0	—	—	0	—	—	0	—	—	0	—	—
Northern redhorse	9	11.51	0.77	15	21.39	1.30	7	7.58	0.89	2	5.30	0.68	1	2.99	0.22	3	6.62	1.00
Carp	93	336.50	22.61	333	1,115.82	67.83	38	157.03	18.39	79	345.12	44.46	132	467.26	33.56	52	217.81	33.09
Channel catfish	183	47.84	3.21	45	6.70	0.41	84	32.17	3.77	57	29.70	3.83	74	17.58	1.26	13	4.72	0.72
Yellow bullhead	1	0.15	0.01	0	—	—	0	—	—	0	—	—	0	—	—	0	—	—
Black bullhead	16	2.98	0.20	1	0.13	0.01	2	0.76	0.09	1	0.86	0.11	3	0.62	0.04	0	—	—
Flathead catfish	33	229.10	15.40	17	43.82	2.66	54	231.72	27.14	18	68.25	8.79	23	43.89	3.15	31	92.58	14.07
Freshwater drum	112	109.48	7.36	86	73.05	4.44	109	77.83	9.11	66	49.87	6.43	181	158.70	11.40	53	51.90	7.89
Subtotal	*899*	*1,443.48*	*97.00*	*773*	*1,578.25*	*95.94*	*491*	*802.67*	*94.00*	*313*	*630.65*	*81.24*	*489*	*763.95*	*54.87*	*183*	*458.12*	*69.61*

SPORT FISHES																		
Pike	0	—	—	0	—	—	2	2 20	0 26	0	—	—	14	35.01	2.51	5	17.07	2 59
Yellow pikeperch	4	3 29	0.22	4	5 51	0 33	1	0 24	0.03	0	—	—	1	0.31	0 02	0	—	—
Sauger	19	14.13	0 95	19	16 57	1 01	8	5 01	0 59	1	1 55	0 20	3	2 49	0 18	0	—	—
Spotted black bass	0	—	—	0	—	—	0	—	—	0	—	—	2	0 93	0.07	0	—	—
Largemouth black bass	0	—	—	1	0 61	0 04	1	0 68	0 08	0	—	—	3	3 63	0.26	2	1.97	0.30
Green sunfish	0	—	—	0	—	—	1	0 06	0 01	0	—	—	0	—	—	0	—	—
Bluegill	0	—	—	1	0 08	0.01	3	0 66	0.08	4	1 76	0 23	69	19.87	1 43	7	1.45	0.22
Warmouth	0	—	—	0	—	—	0	—	—	0	—	—	0	—	—	0	—	—
White crappie	10	0 73	0 05	180	13.12	0.80	46	10.01	1.17	186	55 72	7 18	656	205.36	14.75	410	61 60	9.36
Black crappie	9	0 54	0 04	25	4 41	0 27	25	3 62	0 42	105	29 00	3 74	493	132 68	9 53	156	30.25	4.60
White bass	2	0.26	0 02	5	3 02	0 18	1	0 19	0 02	5	3 27	0 42	9	3 42	0.25	1	0.26	0 04
Yellow bass	2	0 99	0 07	22	8.68	0 53	1	0 64	0 08	7	2 50	0 32	0	—	—	0	—	—
Subtotal	*46*	*19 94*	*1 35*	*257*	*52 00*	*3 17*	*89*	*23 31*	*2 74*	*308*	*93 80*	*12 09*	*1,250*	*403.70*	*29 00*	*581*	*112 60*	*17.11*
PREDATORY FISHES																		
Longnose gar	3	4.70	0.32	2	3 00	0 18	6	6 48	0 76	3	5 33	0 69	1	0 56	0 04	1	2 81	0.43
Shortnose gar	10	10 94	0.73	9	10 59	0 64	17	17 53	2.05	30	41 72	5 38	3	2.97	0.21	12	12 72	1.93
Bowfin	2	6 55	0 44	0	—	—	1	3 02	0.35	1	3 30	0.42	62	217.67	15.63	21	66 96	10 17
Subtotal	*15*	*22 19*	*1 49*	*11*	*13 59*	*0 82*	*24*	*27 03*	*3.16*	*34*	*50 35*	*6.49*	*66*	*221.20*	*15 88*	*34*	*82 49*	*12 53*
FORAGE FISHES																		
Gizzard shad	2	2 32	0.16	26	1 20	0 07	5	0 86	0 10	4	1 38	0 18	7	3.49	0.25	20	4.91	0 75
Total	*962*	*1,487.93*	*100 00*	*1,067*	*1,645.04*	*100 00*	*609*	*853 87*	*100 00*	*659*	*776 18*	*100 00*	*1,812*	*1,392.34*	*100.00*	*818*	*658.12*	*100 00*

* *Carpiodes* spp.

Appendix B, Table 2.—Concluded.

Species	Bellevue, Iowa Aug. 19–30, 1946			Dubuque, Iowa Sept. 1–12, 1946			Total Number of Fish Caught	Total Weight in Pounds	Per Cent of Total Weight
	Number	Weight, Pounds	Per Cent of Weight	Number	Weight, Pounds	Per Cent of Weight			
Commercial Fishes									
Shovelnose sturgeon	0	—	—	1	4 22	0.46	281	364.98	2.64
Mooneye	0	—	—	0	—	—	174	28 68	0.21
Goldeye	0	—	—	0	—	—	84	34.25	0.25
American eel	1	2 35	0 34	3	9 10	1 00	17	47.15	0.34
Blue sucker	0	—	—	0	—	—	5	16.21	0.12
Bigmouth buffalo	26	68 71	9 86	8	38 06	4.18	277	756.48	5.47
Black buffalo	2	10.24	1.47	3	11.22	1 23	29	127.31	0.92
Smallmouth buffalo	5	10 77	1 55	13	11.01	1 21	486	523.64	3.79
Carpsuckers*	13	11.31	1 62	8	7 50	0.82	1,491	1,962.12	14.20
White sucker	2	3 18	0 46	0	—	—	6	9.27	0.07
Spotted sucker	0	—	—	1	1.43	0.16	2	2.34	0.02
Silver redhorse	0	—	—	0	—	—	1	2.57	0.02
Northern redhorse	47	110.74	15.90	9	21.66	2 38	104	207.07	1.50
Carp	42	197 38	28 34	65	322.22	35 35	1,347	4,983.02	36.06
Channel catfish	52	30 00	4.31	64	18.24	2 00	1,115	356.60	2.58
Yellow bullhead	0	—	—	0	—	—	10	4.40	0.03
Black bullhead	0	—	—	13	3.78	0.41	65	19.43	0.14
Flathead catfish	49	85 99	12 35	21	82 31	9 03	294	1,098.75	7.95
Freshwater drum	94	63 27	9 08	104	88.11	9.67	1,088	842.05	6.09
Subtotal	*333*	*593 94*	*85 28*	*313*	*618 86*	*67 90*	*6,876*	*11,386.32*	*82 40*

SPORT FISHES									
Pike	0	—	—	13	33.15	3.64	35	90.92	0.66
Yellow pikeperch	1	0.62	0.09	3	11.71	1.28	17	24.98	0.18
Sauger	3	1.64	0.23	6	5.18	0.57	68	53.96	0.39
Spotted black bass	0	—	—	0	—	—	2	0.93	0.01
Largemouth black bass	1	1.02	0.15	4	4.40	0.48	18	20.72	0.15
Green sunfish	0	—	—	0	—	—	3	0.31	0.00
Bluegill	27	2.86	0.41	101	21.68	2.38	308	71.31	0.52
Warmouth	0	—	—	1	0.61	0.07	10	3.84	0.03
White crappie	175	42.25	6.07	217	51.16	5.61	2,677	705.67	5.11
Black crappie	77	18.31	2.63	183	71.90	7.89	1,452	394.25	2.85
White bass	44	17.57	2.52	12	4.87	0.53	162	59.00	0.43
Yellow bass	1	0.66	0.09	0	—	—	258	81.74	0.59
Subtotal	*329*	*84.93*	*12.19*	*540*	*204.66*	*22.45*	*5,010*	*1,507.63*	*10.92*
PREDATORY FISHES									
Longnose gar	1	2.70	0.39	8	10.33	1.13	38	93.47	0.68
Shortnose gar *	5	6.76	0.97	17	18.51	2.03	209	246.01	1.78
Bowfin	3	7.73	1.11	16	46.34	5.08	154	514.15	3.72
Subtotal	*9*	*17.19*	*2.47*	*41*	*75.18*	*8.24*	*401*	*853.63*	*6.18*
FORAGE FISHES									
Gizzard shad	10	0.41	0.06	73	12.83	1.41	237	69.91	0.50
Total	*681*	*696.47*	*100.00*	*967*	*911.53*	*100.00*	*12,524*	*13,817.49*	*100.00*

* *Carpiodes* spp.

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Tularemia, Weather, and Rabbit Populations

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FOREWORD

IT IS commonly assumed, by people who are not immediately associated with research, that endeavors in this field of activity can be completed in a short time and that findings of value will always accrue. This assumption is often, but not by any means always, valid. Further, short-term researches almost universally have their base in painstaking studies which have progressed over a long period, some time previous to the initiation of the short-term observations. Values which result from research studies are often so closely intertwined with time that these values do not become significant until observations have been continued over a long period. This is the case in the present important contribution, a study correlating game populations, weather, and human health, and utilizing observations covering about a quarter of a century.

Dr. Thompson was zoologist for the Illinois Natural History Survey from 1923 to 1944 and, since that time, has been Senior Naturalist for the Forest Preserve District of Cook County, Illinois. Because of his earlier training in animal pathology and statistics, he became interested in tularemia soon after the first cases were reported in Illinois. In 1934 Dr. Yeatter, a specialist in research and management of upland game in the Middle West, joined our staff and teamed up with Dr. Thompson to work on the relation of human tularemia to rabbit hunting in Illinois. Dr. Yeatter has been principally responsible for completing the project during the past 10 years and for preparing this manuscript for publication. These men noticed the relationship between mild autumn temperatures and the severe outbreaks of human tularemia which occurred in Illinois following the opening of the rabbit-hunting seasons in 1938 and 1939. Later they learned that Dr. Robert G. Green of Minnesota had already foreseen this relationship from a consideration of the life history of the ticks which transmit the infection from rabbit to rabbit and from a study of the course of the disease in the cottontail.

The following study should be of interest to a great many people.

HARLOW B. MILLS, *Chief*
Illinois Natural History Survey

CONTENTS

Hunters in an uncultivated gray soil prairie area in southern Illinois. This part of the state, which has a large cottontail population, has a relatively high human tularemia rate.

Tularemia, Weather, and Rabbit Populations

RALPH E. YEATTER*
DAVID H. THOMPSON*

TULAREMIA, a disease of rabbits and hares (lagomorphs), rodents, and several other animals, is transmissible to man. In the period 1926–1949, Illinois had more than 3,000 reported cases of human tularemia, about twice as many as any of the other states. The great majority of these Illinois cases were traceable to contact with cottontail rabbits, fig. 1.† Because these rabbits are widely distributed on agricultural lands throughout Illinois, and because they are able to maintain themselves under heavy hunting pressure, they rank among the chief game animals of the state. At one time, cottontail rabbits probably made up about two-thirds of the total game bag of Illinois hunters, but, since the tularemia hazard has become generally recognized, rabbit hunting has lost some of its former popularity. Thus, tularemia is of concern to many thousands of people in Illinois not only because of its relation to public health, but also because of its adverse effect on the sport of hunting.

This paper deals with the relation of human tularemia in different parts of the state and in different years to weather, to the abundance of rabbits, and to some other aspects of its epidemiology. In analyzing the information on tularemia in Illinois, the writers have made an effort to determine the methods of management which would permit Illinois hunters to enjoy the sport of rabbit hunting without undue risk of infection. In a report by the writers (Thompson & Yeatter 1941) at the Seventh Midwest Wildlife Conference, Des Moines, Iowa, December, 1941, and in a Natural History Survey release (Anonymous 1941), the writers stated that the human tularemia rate in Illinois is related to weather at the time of the opening of the hunting season. They added that in years in which the mean date of the first 10 freezing nights of autumn occurs before the opening of the rabbit-hunting season, the tularemia rate among humans in the state is much lower than in other years. Green (1935, 1939) had previously pointed out that in Minnesota rabbits are free of tularemia during the cold months of the year and had suggested delaying the hunting of rabbits until middle or late October as a way of reducing the hazard of tularemia in human beings.

The Illinois records on tularemia and weather for the decade following the publication of the writers' first reports appear to support the conclusion that the tularemia rate and weather are closely related. Also, as was previously indicated (Thompson & Yeatter 1941), it is evident that the tularemia rate in Illinois may be influenced strongly at times by fluctuations of rabbit populations. The principal conclusion resulting from the present study is that, because of certain characteristics of the life history of the principal arthropod vector, the incidence of human tularemia in Illinois can be lowered significantly by delaying the opening of the rabbit-hunting

*Dr. Yeatter holds the title of Game Specialist with the Illinois Natural History Survey. Dr. Thompson, for several years with the Illinois Natural History Survey, is now Senior Naturalist of the Forest Preserve District of Cook County, with headquarters at River Forest, Illinois.

†The Mearns cottontail rabbit, *Sylvilagus floridanus mearnsi* (Allen), is the common rabbit in Illinois. South of the Ozarkian Uplift, in extreme southern Illinois, its range intergrades with that of the Oklahoma cottontail rabbit, *S. f. alacer* (Bangs), according to Hamilton (1943). Other Lagomorpha in Illinois are the swamp rabbit, *Sylvilagus aquaticus aquaticus* (Bachman), distributed in wooded bottomlands of a few southern counties, and the white-tailed jack rabbit, *Lepus townsendii campanius* Hollister, which occurs in small numbers in the northwestern part of the state.

Fig. 1.—A Mearns cottontail rabbit. This rabbit is an important game animal throughout its range from New York to Kansas. In Illinois, it is the reported source of more than 90 per cent of the human tularemia cases.

season until about December 1. Such delay is urgent, particularly in the central and southern parts of the state.

Acknowledgments

The writers are greatly indebted to the Illinois Department of Public Health for detailed records since 1926 on the distribution of tularemia cases in Illinois and to the United States Public Health Service for information on the prevalence of tularemia in other parts of the country. They are indebted also to the Wisconsin Conservation Department for permission to use its records of the annual kill of cottontail rabbits in Wisconsin, to the United States Forest Service for census data on a southern Illinois area, and to Joe L. Mote of Watseka, Illinois, for bag records and field notes.

History of Tularemia

Tularemia was discovered in 1910 by Dr. George W. McCoy of the United States Public Health Service in the ground squirrels of Tulare County, California (McCoy 1911; Francis 1937). The disease was named in 1920 by Dr. Edward Francis (1921, 1937), also of the United States Public Health Service, after he had established the identity of the ground squirrel disease with an outbreak of "Deerfly fever" in man in Utah. The essential facts about tularemia have been worked out entirely by American investigators. The causative organism is a bacterium, *Pasteurella tularensis* (McCoy & Chapin) Bergey *et al.* (McCoy & Chapin 1912; Breed, Murray, & Hitchens 1948). In spite of the short history of tularemia, it is believed that this disease is not new but

is an old one which was not identified until comparatively recent years. Since 1925 it has been reported from all states except Vermont, as well as from Canada, Alaska, Mexico, and several countries in Europe, Asia, and Africa.

Tularemia in Wildlife

Burroughs *et al.* (1945) have listed 47 kinds of mammals and birds, distributed chiefly in North America, Europe, and Asia, in which natural infection with tularemia has been shown by laboratory tests. Various groups of lagomorphs and rodents make up more than three-fourths of their list. Also included are certain gallinaceous birds, raptorial birds, and carnivores, as well as a few domestic animals.

A few years ago, wildlife pathologists of the University of Minnesota and the United States Bureau of Biological Survey (now the Fish and Wildlife Service), co-operating with the Minnesota Department of Conservation, studied the relation of tularemia to the welfare of several wildlife species in Minnesota. As a result of these studies, Green (1939) reported that cottontail rabbits are highly susceptible to tularemia, and that infected cottontails invariably die, usually within a week after the onset of the disease. He found that snowshoe hares are resistant to the disease and that they seldom die from it. Jack rabbits prove rather susceptible when exposed, but, among wild jack rabbits in Minnesota, tularemia is apparently rare.

Green & Wade (1929) reported a fatal tularemia infection in the bob-white, *Colinus virginianus* Linnaeus; Green & Shillinger (1932) found the disease in the ruffed grouse, *Bonasa umbellus togata*, and the sharp-tailed grouse, *Pediocetes phasianellus*. Green (1939) stated that the ring-necked pheasant is highly resistant to infection, but that muskrats "suffer from a highly fatal infection." He reported that all kinds of mice, squirrels, and other small rodents in Minnesota are susceptible, and suggested that mice may be an important reservoir of the disease in the wild.

Green & Wade (1928) found that domestic cats contracted tularemia when fed the carcasses of infected guinea pigs. Green (1942) stated that dogs appear to be almost entirely immune. Waller (1940), however, reported agglutination tests positive for tularemia in blood samples of a dog which became sick after feeding on a diseased rabbit. Downs *et al.* (1946) were successful in infecting a number of laboratory dogs by injection of virulent tularemia organisms, but reported that dogs were less susceptible to the disease than most laboratory animals and that they were often able to localize the infection.

Lillie & Francis (1936) reported as follows on attempted experimental inoculation of red foxes: "In 1934 four red foxes (*Vulpes fulva*) were obtained. One (7484) was injected subcutaneously with infected guinea pig spleen and culture (Omo strain), and died 13 days later. He refused to eat during the entire period. There was a diarrhea during the last 2 days of life. Two other foxes died 2 months after the subcutaneous inoculation of 7760 and after the first infectious feeding of 7761. Both of these animals had had noisy labored respiration; the first for some 4 weeks, the second for 3 or 4 days before death.

"*B. tularense* was recovered directly from the blood of 7484, and inoculation of various organs of all three reproduced tularaemia in guinea pigs and cultures were recovered."

Human beings sometimes become infected with tularemia through being bitten, scratched, or clawed by dogs, cats, or other flesh-eating animals that have become contaminated with the tissue or blood of infected wildlife.

A considerable number of animal species in which natural infection has not been proved have been reported as probable sources of human tularemia. Francis (1937) mentioned as suspected carriers the coyote, red fox, deer, ground hog, tree squirrel, skunk, sage hen, bull snake, and hog. Of domestic rabbits, Francis stated, "Rabbits raised under domestic conditions in rabbitries and hutches, although highly susceptible, have not been found naturally infected, due probably to their freedom from ticks."

Tick and Insect Vectors

Tularemia is spread among wild animals largely by the bites of ticks and insects.

Fig. 2.—Rabbit tick, *Haemaphysalis leporis-palustris* (Packard). *Top,* male; *center,* female; *bottom,* female, engorged. The rabbit tick is the chief agent in the spread of tularemia among rabbits and is an important carrier of the disease in other kinds of wildlife.

Infection in carnivorous mammals and birds may, of course, come from eating diseased prey. Also, it seems probable that certain aquatic mammals, and possibly other forms, sometimes contract the disease from water that is contaminated with *Pasteurella tularensis.* For example, the findings of Jellison *et al.* (1942) suggest that water-borne disease organisms were the source of a tularemia outbreak among beavers in Montana in 1939 and 1940.

Studies by Parker *et al.* (1951) indicate that contamination of streams and mud with tularemia organisms is widespread in the northwestern United States, and that fatal infections of muskrats and beavers with tularemia probably have occurred there in recent years.

The rabbit tick, *Haemaphysalis leporis-palustris* (Packard), fig. 2, is the chief arthropod vector of tularemia in the wild. Francis (1937) stated, "The disease . . . . is spread from rabbit to rabbit principally by the rabbit tick, *Haemaphysalis leporis-palustris,* but also by other blood-sucking arthropods—ticks, lice, and fleas. The rabbit tick, the rabbit louse, and the rabbit flea do not bite man, and therefore they are not a source of human infection."

Green (1942) reported that the rabbit tick was principally responsible for the spread of tularemia among wild animals and birds in Minnesota.

Two other ticks, the American dog tick, *Dermacentor variabilis* (Say), fig. 3, and the Rocky Mountain wood tick, *D. andersoni* Stiles, fig. 4, are known vectors of tularemia. Both are sources of the disease in man as well as in various species of wildlife. The American dog tick, *D. variabilis* (also called wood tick), is distributed in the eastern United States, in the Mississippi River valley, and in some of the Plains states as well as in western California, Canada, and Alaska (Cooley 1938). Green (1942) reported that the most common mode of human tularemia infection in Minnesota appeared, at the time he wrote, to be the bite of a "wood tick" (American dog tick) and the second most common the cleaning of an infected rabbit. He found that the adult dog ticks that carry tularemia are those that have become infected during immature stages while feeding on diseased mice or other small rodents.

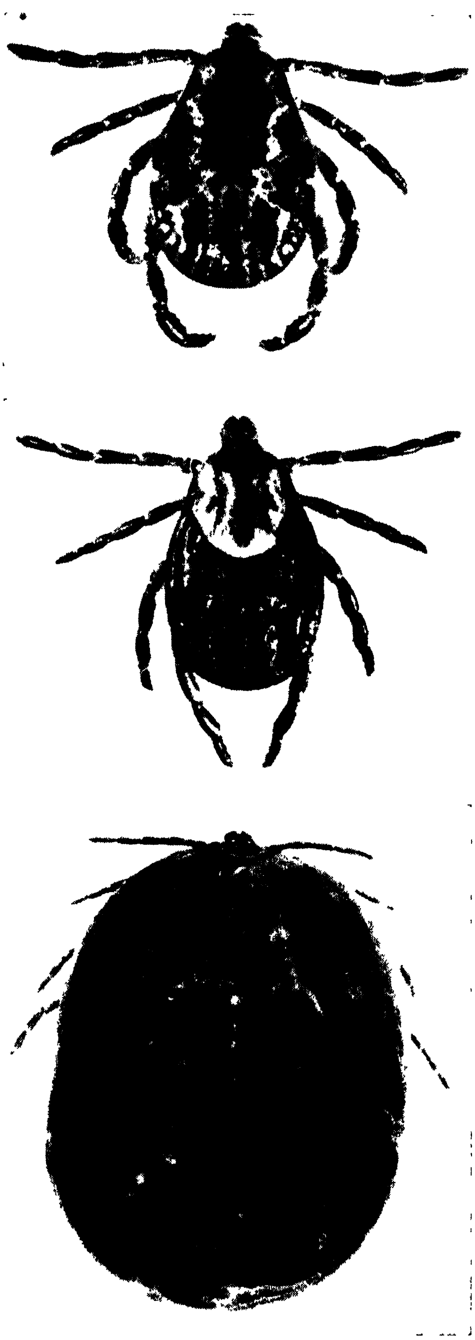


Fig. 3.—American dog tick, *Dermacentor variabilis* (Say). *Top,* male; *center,* female; *bottom,* female, engorged. This tick is widely distributed in North America; its principal range is east of the Rocky Mountains. It is a source of tularemia in humans and probably in various wild and domestic animals.

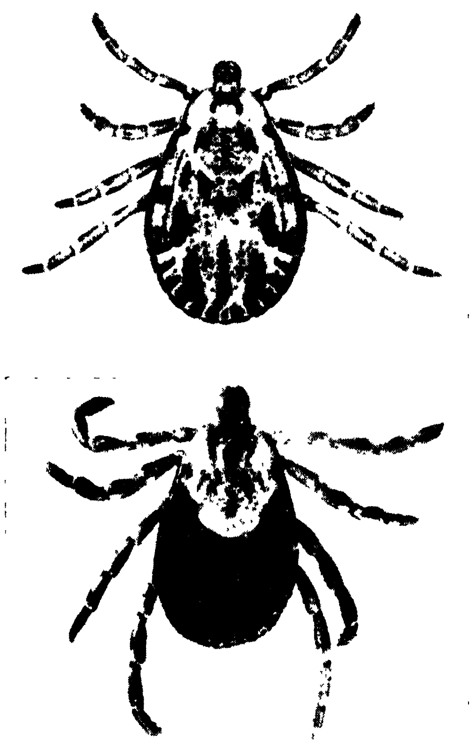


Fig. 4.—Rocky Mountain wood tick, *Dermacentor andersoni* Stiles. *Top,* male; *bottom,* female. This tick is a source of tularemia in humans and probably in domestic animals and wildlife. It is found in western parts of the North American continent.

Bell (1945) reported that a natural barrier, apparently a bactericidal action of the ticks' guts, keeps infection among dog ticks at a relatively low level. Green (1942) reported a maximum of only 1 infected to about 2,500 uninfected dog ticks in numerous tick samples collected in Minnesota. He noted that dog ticks in Minnesota go into a resting period in July and remain dormant until the following spring, and that they cause infection principally in May and June, just previous to becoming dormant.

The Rocky Mountain wood tick is distributed in southwestern Canada and in the western United States from the arid zone east of the Rocky Mountains westward to central Washington, central Oregon, and eastern California. Both immature and adult stages have been found

on a wide variety of mammals and birds (Cooley 1938). The adult stage has been reported as a source of human tularemia in several western states. Wood ticks are believed to have caused a tularemia outbreak among range sheep in Montana (Philip, Jellison, & Wilkins 1935).

Several kinds of insects are known to be carriers of tularemia. Prince & McMahon (1946) stated that the disease has been transmitted under experimental conditions by the bites of several insects, including deer flies, *Chrysops discalis* Williston, stable flies, *Stomoxys calcitrans* (Linnaeus), bed bugs, *Cimex lectularis* Linnaeus, and mosquitoes, *Aedes aegypti* (Linnaeus).

Lice and fleas, mentioned as vectors by Francis (1937), appear to be potentially important in the dissemination of tularemia in the northern states because they remain active in winter when most arthropod vectors are dormant. Ecke (1948) found that flea populations on Illinois cottontails were higher in winter than at other seasons. Evidence apparently is lacking, however, that either fleas or lice frequently transmit tularemia. Prince & McMahon (1946) reported that guinea pigs used in their transmission experiments remained negative for tularemia after exposure during 32 days to infected rat fleas, *Xenopsylla cheopis* (Rothschild), and California ground squirrel fleas, *Diamanus montanus* (Baker). They concluded that the two species of fleas tested do not play an important role in the spread of the disease. Green (1942) stated, "Fleas are found on rabbits in southern Minnesota during the winter; but, although these insects can transmit tularemia, they appear to do so rarely."

Hopla (1951) found that tropical rat mites, *Bdellonyssus bacoti* (Hirst), retained tularemia organisms for considerable periods after feeding on infected mice. Normal mice became infected when they crushed infected mites orally, but not when they were bitten by the mites.

Tularemia in Man

Francis (1937) stated that wild rabbits and hares are the source of more than 90 per cent of all human tularemia cases in the United States. Humans generally become infected from contact of the bare hands with the flesh or blood of infected rabbits or from eating infected rabbit flesh that is insufficiently cooked. Usually infection from handling a diseased rabbit develops at the site of a scratch or puncture in the skin, but occasionally it develops in the eye as a result of contact with hands or of spattering of washings during cleaning. There is considerable evidence that the disease organism also is able to penetrate the unbroken human skin.

Francis (1937) described a typical tularemia case as follows: "About 3 days after exposure to infection, illness begins with headache, chilliness, vomiting, aching pains all over the body, and fever. The patient thinks that he has the 'flu' and goes to bed. The sore on the hand develops into an ulcer. The glands at the elbow or in the armpit become enlarged, tender, and painful, and later may develop into an abscess. There is sweating, loss of weight, and debility. Illness lasts about 3 weeks and is followed by a slow convalescence covering a period of 2 or 3 months. Most patients recover without any bad after effects, but about 5 percent die, especially if the case is complicated by pneumonia." Although there is no evidence of a natural immunity in man, persons who have recovered from the disease are permanently immune.

In regard to the diagnosis of the disease, Francis (1937) wrote: "The history of tick-bite, fly-bite, or wild rabbit contact especially, or contact with other animals, when coupled with fever, an ulcer on the skin, and regional lymph-node enlargement, should call attention to tularaemia. Diagnosis is made conclusive by obtaining agglutination of *Bacterium tularense* [*Pasteurella tularensis*] by the patient's serum or by obtaining a culture of the organism from the patient's ulcer or lymph nodes following guinea pig inoculation, or by obtaining a positive skin reaction using an antigen prepared by Foshay of Cincinnati for intradermal injection."

As will be discussed later, treatment of tularemia in man has been facilitated in recent years by the use of antibiotics.

Distribution in the United States.—It will be evident from fig. 5, showing the distribution of 23,921 cases of tularemia reported in the United States during

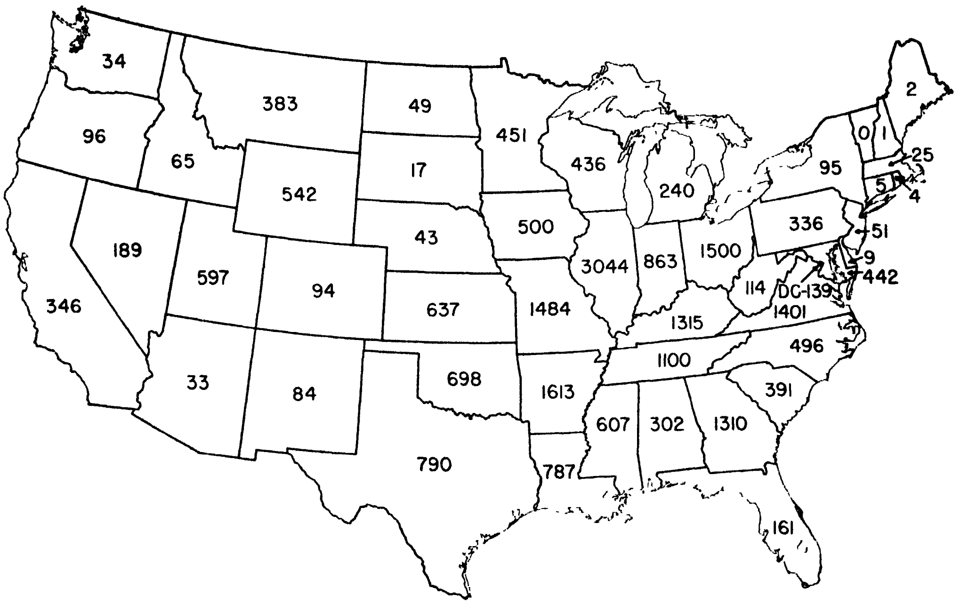


Fig. 5.—Total numbers of reported human tularemia cases in the various states during the period 1924–1949. Data from records of the United States Public Health Service.

the period 1924–1949, that the largest number of cases occurred in states lying in the central and south central portions of the eastern half of the country. Jellison & Parker (1945), who emphasize the importance of cottontail rabbits as a source of tularemia in humans, pointed out that cottontails and closely related forms are the only kinds of wild rabbits native to much of the region mentioned above.

Table 1.—States that reported a total of 500 or more cases of tularemia, 1924–1949.*

STATE	NUMBER OF CASES
Illinois	3,051
Arkansas	1,613
Ohio	1,500
Missouri	1,484
Virginia	1,401
Kentucky	1,315
Georgia	1,310
Tennessee	1,100
Indiana	863
Texas	790
Louisiana	787
Oklahoma	698
Kansas	637
Mississippi	607
Utah	597
Wyoming	542
Iowa	500

*Data from United States Public Health Service records except Illinois figure, which is from Illinois Department of Public Health and higher than figure from federal agency.

The states which, according to the records of the United States Public Health Service, reported 500 or more cases of tularemia in the period 1924–1949 are listed in table 1. Illinois, with more than 3,000 cases, reported the largest number, followed by Arkansas with 1,613 and Ohio with 1,500 cases. Although Illinois had the largest human population among the 17 states listed, more than one-half of all tularemia cases reported in Illinois in 1936–1949 were from counties in the southern third of the state, which had only about 12 per cent of the state's population.

Preliminary studies indicated that the human tularemia rate in Illinois and nearby states tended to fluctuate, but it was evident that the particular years in which increases, or decreases, occurred often were not the same in all parts of a geographic region. For example, in one year, 1938, there was a decline of about 50 per cent in the tularemia rate in the northern Great Lakes states, but at the same time there was a severalfold increase in Illinois and the regions adjoining it on the east and west. Later, in 1941,

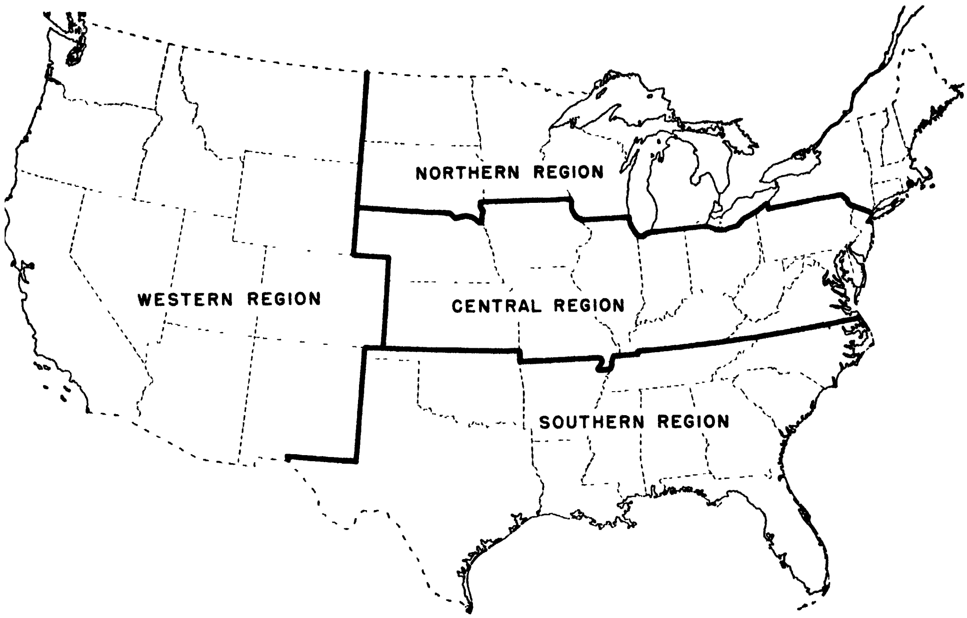


Fig. 6.—Four general regions of the United States which exhibit distinctive trends and seasonal distribution of human tularemia.

when tularemia declined in Illinois, Indiana, and Iowa, there was a moderate increase in the states to the north.

With respect to human tularemia rates and seasonal distribution, the United States may be divided conveniently into four major regions, namely, Northern, Central, Southern, and Western, fig. 6. Trends in the annual tularemia rates during the period 1935–1949 in these four

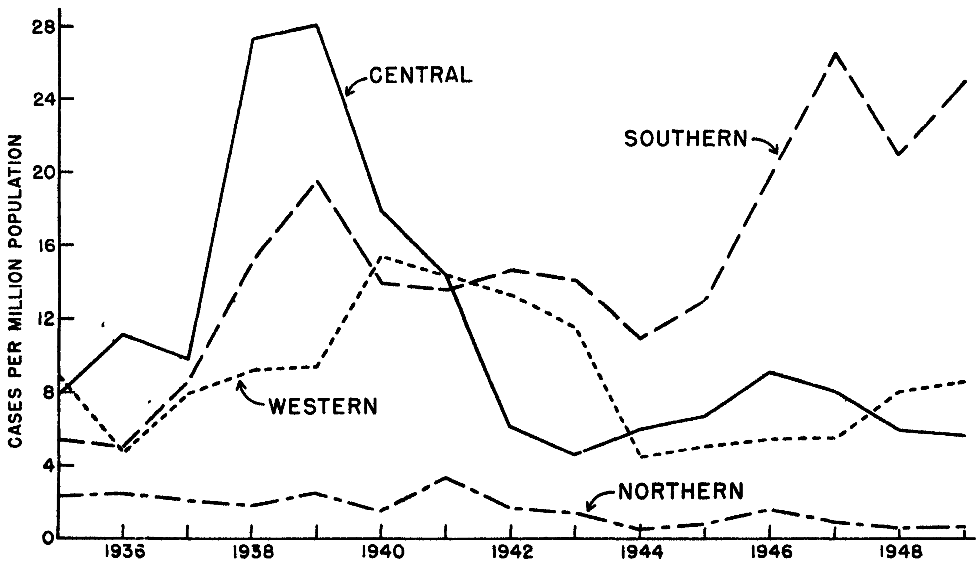


Fig. 7.—Trends in human tularemia rates during the period 1935–1949 in the four regions of the United States shown in fig 6. Data on which this graph is based are from records of the United States Public Health Service.

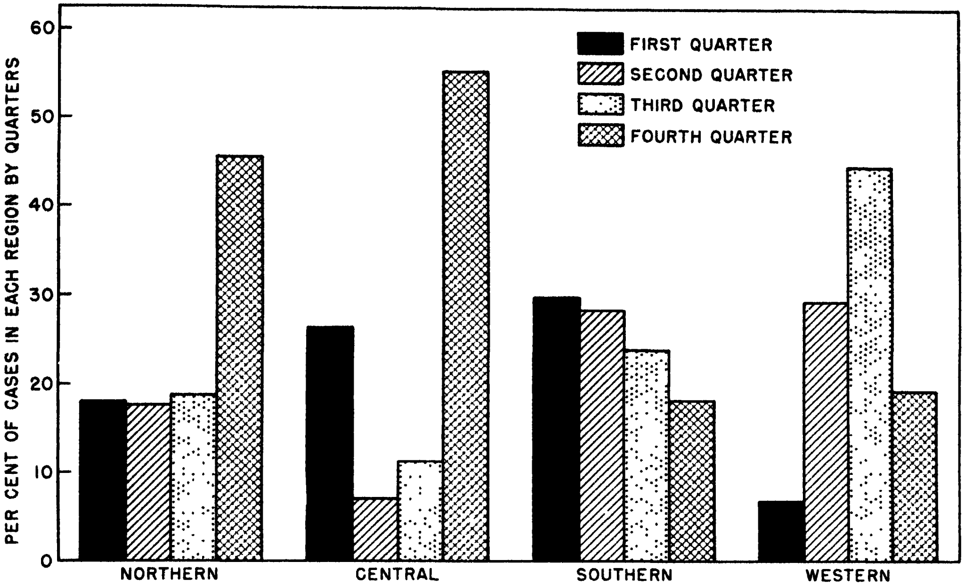


Fig. 8.—Distribution of reported human tularemia cases by quarters of the year during the period 1939–1949 in the four regions of the United States shown in fig. 6. Data on which this graph is based are from records of the United States Public Health Service.

regions are shown in fig. 7. The seasonal distribution of tularemia in these regions is shown in table 2 and fig. 8.

In the Northern and Central regions the majority of cases occur during late autumn and early winter. Rabbits, which are hunted at that time, cause most of the cases. As indicated by table 3, furbearers, squirrels, and upland game birds contribute a few cases. During other seasons, these regions show moderate numbers of cases that, presumably, result from bites of ticks or insects, from chance infections by a variety of mammals or birds, both wild and domestic, or from a small amount of year-round hunting.

In the Southern Region, the human tularemia rate is fairly uniform throughout the year, indicating several sources of infection, the most important of which are rabbits, ticks, and insect vectors. Francis (1937) recorded 65 cases of tularemia in the southern states, chiefly from March through July, due to contact with dog ticks, *Dermacentor variabilis*. Pullen & Stuart (1945) reported that 176 (92.1 per cent) of 191 tularemia cases for which the apparent source was recorded in Louisiana during a 16½-year period gave a history of contact with rabbits. In this region, year-round hunting probably plays an important part in transmission of tularemia to human beings.

The human tularemia rate in the Western Region is highest in summer. Because the principal insect and tick vectors in this region are most active from late spring to late summer, it appears that arthropods may play a relatively greater part in transmitting tularemia to humans there than in the Northern and Central regions. Wood ticks, *Dermacentor andersoni*, were reported by Francis (1937) to have caused more than 50 cases in Montana and surrounding states. According to the United States Public Health Service (Anonymous 1940), sheep handlers have occasionally become infected from contact with wood ticks or tick feces in the wool. Jellison (1950) listed, for the western states, 158 cases of tularemia probably caused by deer fly bites, and showed that the distribution of these cases corresponded roughly with the distribution of the deer fly species, *Chrysops discalis* Williston. Jellison *et al* (1950) reported contamination with *Pasteurella tularensis* organisms of certain natural waters in Montana and also a few cases of human tularemia caused by a contaminated domestic water supply.

Table 2.—Summary of reported tularemia cases in four major regions of the United States, by quarters and years, 1939–1949. (Data from annual reports of the United States Public Health Service on the incidence of communicable diseases.)

Year	Northern Region[1]					Central Region[2]					Southern Region[3]					Western Region[4]				
	Quarter				Total for Year	Quarter				Total for Year	Quarter				Total for Year	Quarter				Total for Year
	1	2	3	4		1	2	3	4		1	2	3	4		1	2	3	4	
1939	5	9	9	57	80	291	36	90	1,007	1,424	209	153	101	142	605	12	29	57	30	128
1940	10	8	11	24	53	368	45	78	444	935	176	103	86	74	439	10	70	105	29	214
1941	21	15	15	64	115	127	37	68	509	741	105	121	111	90	427	12	68	86	33	199
1942[5]	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1943	6	11	16	16	49	91	32	38	77	238	134	167	90	50	441	6	70	64	19	159
1944	6	4	4	4	18	40	18	32	220	310	78	121	95	49	343	3	16	34	9	62
1945	6	4	11	7	28	117	36	46	150	349	116	102	112	78	408	3	25	32	11	71
1946	11	12	9	24	56	76	44	56	294	470	152	143	176	148	619	11	22	25	17	75
1947	11	5	10	6	32	180	52	84	106	422	261	233	201	120	815	6	13	37	20	76
1948	3	9	2	6	20	82	29	63	130	304	146	230	147	134	657	6	17	55	34	112
1949	6	7	2	8	23	74	54	62	100	290	266	203	197	119	785	14	26	47	33	120
Total	*85*	*84*	*89*	*216*	*474*	*1,446*	*383*	*617*	*3,037*	*5,483*	*1,643*	*1,576*	*1,316*	*1,004*	*5,539*	*83*	*356*	*542*	*235*	*1,216*

[1]*Northern Region* Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, Michigan, Wisconsin, Minnesota, North Dakota, South Dakota.
[2]*Central Region:* New Jersey, Pennsylvania, Delaware Maryland, District of Columbia, Virginia, West Virginia, Ohio, Indiana, Illinois, Kentucky, Iowa, Missouri, Nebraska, Kansas.
[3]*Southern Region:* North Carolina, South Carolina, Georgia, Florida, Tennessee, Alabama, Mississippi, Arkansas, Louisiana, Oklahoma, Texas.
[4]*Western Region.* Montana, Idaho, Wyoming, Colorado, New Mexico, Arizona, Utah, Nevada, Washington, Oregon, California.
[5]Records for 1942 are omitted because quarterly summaries are lacking The total numbers of reported cases for 1942 are as follows Northern Region, 58; Central Region, 317; Southern Region, 464, Western Region 185.

Jack rabbits, *Lepus* spp., are the reported source of a number of cases in the Western Region. These rabbits also are important hosts of ticks and probably of biting flies that carry the disease (Jellison & Parker 1945). Jellison (letter of April 24, 1951, from Hamilton, Montana) states, "Cottontails have not been as important in this area as other sources of infection."

Distribution in Illinois.—Records of the Illinois Department of Public Health indicate that cottontail rabbits are responsible for the great bulk of human tularemia in Illinois. According to Sharp (1939) all but 2 of 459 reported cases in the state in 1938, during a severe outbreak of the disease, were traceable to contact with cottontail rabbits. McDaniels (1943) stated that cottontails cause more than 95 per cent of the human tularemia cases in Illinois. Other mammals, birds, ticks, and blood-sucking insects probably serve as the source of infection for most of the other cases, as numerous infections have been traced to them elsewhere in the United States.

Recent studies by Jackson (1946) in Indiana and Morgan (1949) in Wisconsin, table 3, show somewhat higher percentages of cases caused by vectors other than rabbits reported for these states than for Illinois. As has already been shown, the proportion of tularemia cases caused by the several kinds of known vectors varies with different sections of the country.

The mortality rates from human tularemia cases reported in Illinois during the period 1926–1951 averaged 5.7 per cent, table 4. Considerable variation in the mortality rates was apparent from year to year. It is of interest in this regard that Philip & Davis (1935), Green (1943), and others isolated several strains of tularemia from naturally infected animals. These strains differed widely in virulence. Green's work indicated that the virulence of the disease depended largely on the kind of animal from which it came. For example, he found that the virulence of tularemia from infected grouse was considerably lower, when measured by the

Table 3.—Reported sources of human tularemia in Wisconsin (379 cases in which the cause was reported) and Indiana (123 cases). Data from Morgan (1949) and Jackson (1946).

Reported Source of Infection	Wisconsin		Indiana	
	Number of Cases	Per Cent of Total	Number of Cases	Per Cent of Total
Mammal	*340*	*89 7*	*117*	*95 1*
Rabbit	305	80.5	108	87 8
Muskrat	10	2.6	2	1 6
Cat	9	2 4	1	0 8
Dog	8	2 1	—	—
Squirrel	4	1 1	5	4 1
Skunk	2	0 5	—	—
Horse	2	0.5	—	—
Opossum	—	—	1	0 8
Upland Game Bird	*11*	*2.9*	*1*	*0 8*
Partridge, pheasant, or prairie chicken	11	2 9	—	—
Pheasant	—	—	1	0 8
Arthropod	*27*	*7 1*	*5*	*4 1*
Tick	24	6 3	4	3 3
Deer fly	3	0.8	—	—
Sweat bee	—	—	1	0.8
Water	*1*	*0 3*	—	—
Total	*379*	*100 0*	*123*	*100 0*

Table 4.—Data on human tularemia reported by the Illinois Department of Public Health 1926–1951.

YEAR	CASES	DEATHS	PER CENT MORTALITY
1926	1	—	—
1927	14	—	—
1928	10	—	—
1929	36	1	2.8
1930	139	2	1.4
1931	126	4	3.2
1932	134	4	3.0
1933	172	9	5.2
1934	134	11	8.2
1935	69	4	5.8
1936	91	6	6.6
1937	109	5	4.6
1938	459	32	7.0
1939	485	42	8.7
1940	272	23	8.5
1941	106	6	5.7
1942	67	1	1.5
1943	55	1	1.8
1944	91	10	11.0
1945	131	6	4.6
1946	97	9	9.3
1947	123	1	0.8
1948	57	2	3.5
1949	73	0	0.0
1950	80	2	2.5
1951	74	0	0.0
Total	*3,205*	*181*	—
Average	—	—	5.7

survival time of inoculated guinea pigs, than that from rabbits. After serial passage of these strains through guinea pigs, however, the virulence of the two strains became identical.

According to a publication of the Illinois Department of Public Health (Anonymous 1939) tularemia in man "may be mild in character although greatly reducing physical efficiency. For that reason a great many cases undoubtedly escape notification. . . . [The disease is] probably considerably more prevalent in Illinois than case reports indicate."

Hicks (1942) has suggested that some rabbit hunters, as a result of mild infections, may acquire a degree of immunity to tularemia. He wrote: "If there is such a thing as partial or complete immunity, it may be due to a former infection so mild as to have gone unrecognized, or, more likely, to resistance acquired by frequent but slight inoculations obtained through being bitten by ticks or other vectors."

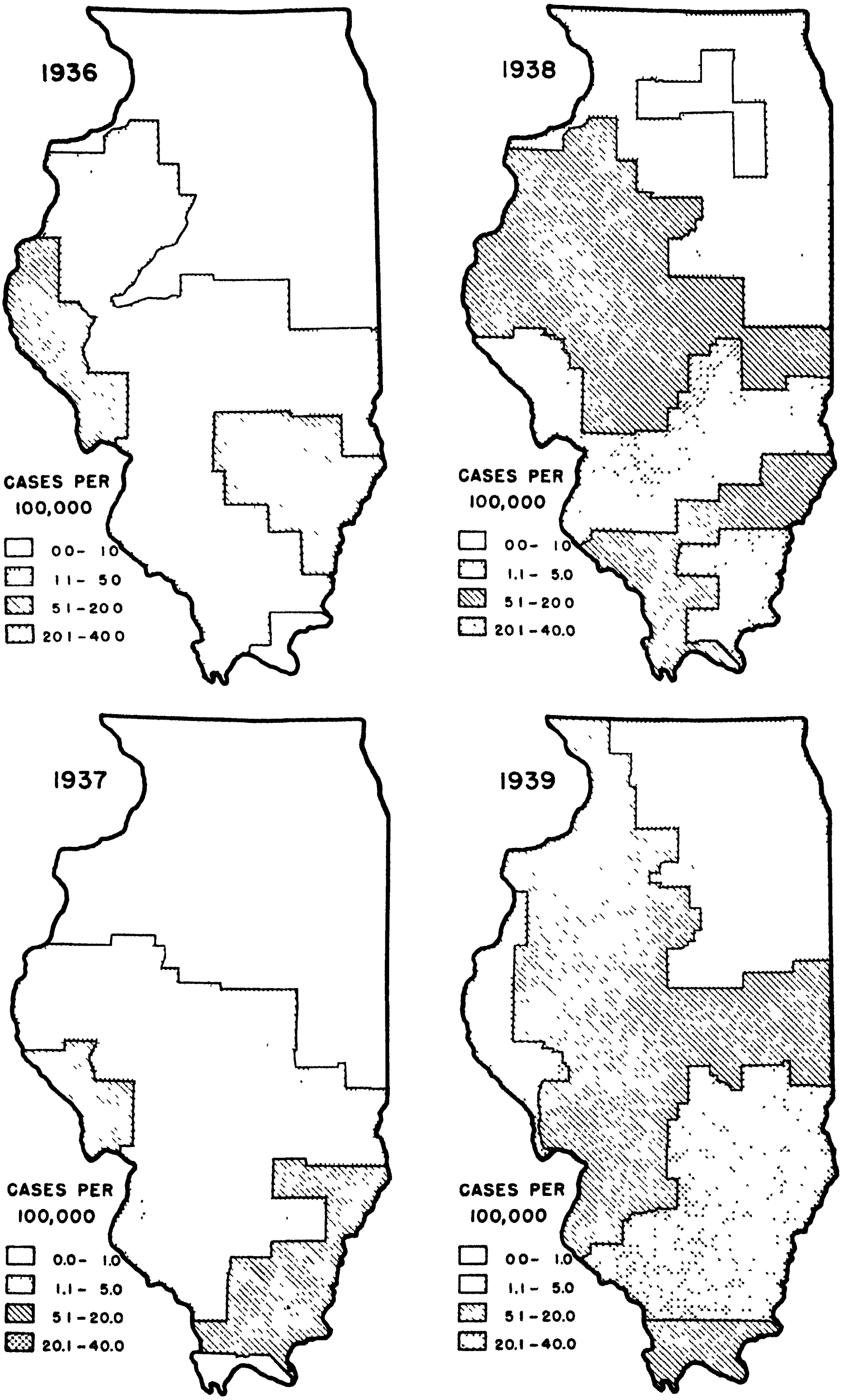
The first known case of human tularemia in Illinois was reported in 1926. By 1930 the annual total of reported cases exceeded 100. A summary of the data on tularemia in Illinois during the period 1926–1951 is shown in table 4. The small number of cases reported early in this period probably reflects lack of experience on the part of many physicians in identifying the disease.

The distribution of human tularemia in Illinois in each year of the 14-year period 1936–1949 (the years of most intensive study of rabbit populations in relation to incidence of human tularemia) is presented in figs. 9–22. Because the number of cases in most counties was too small to be treated statistically, and because hunters commonly go into neighboring counties to hunt, the data have been "smoothed" in order to determine general trends in prevalence of the disease over the state. This "smoothing" of the data was done for each county by averaging the number of cases and the populations with comparable data for all adjoining counties.

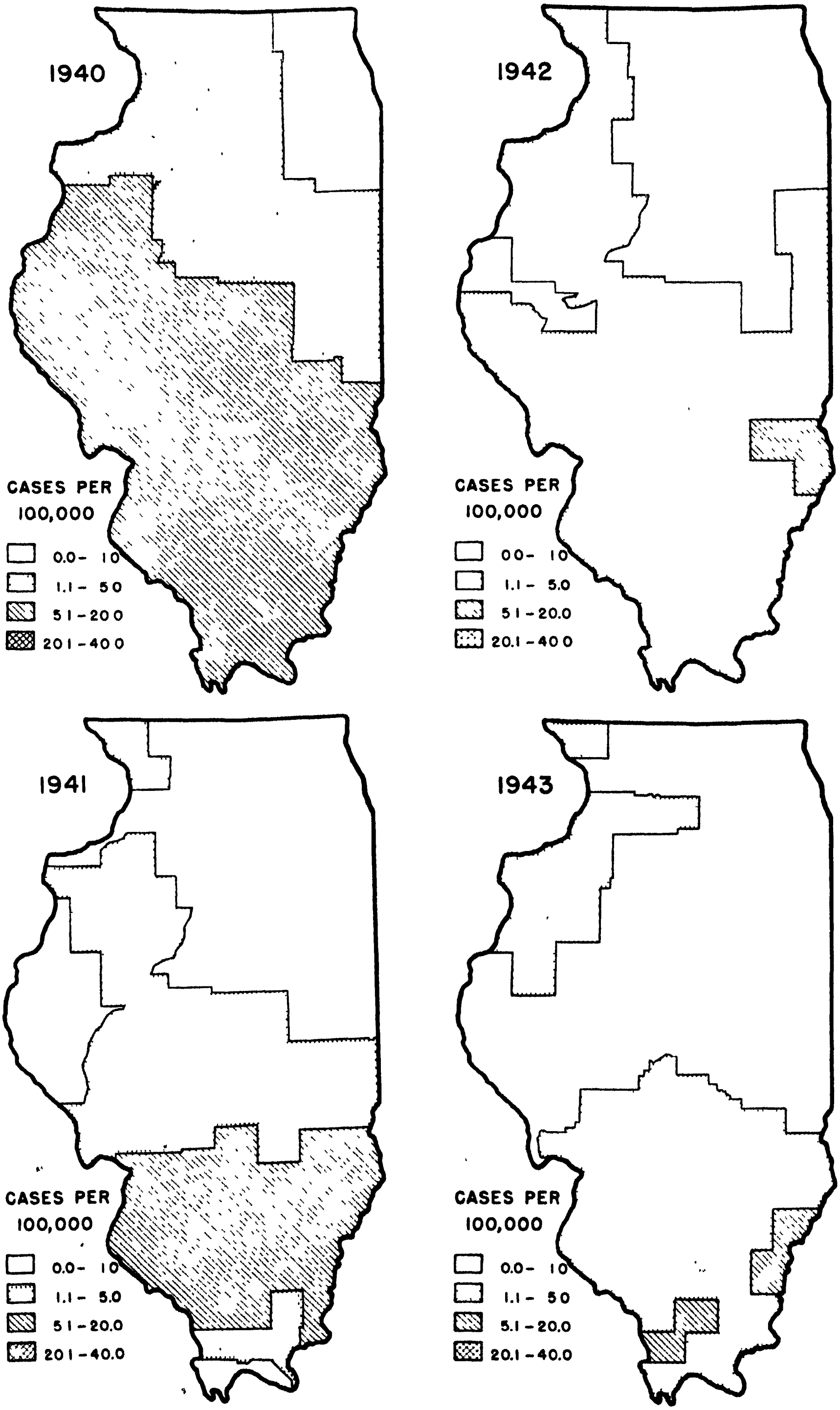
When the tularemia rate was calculated on the basis of numbers of hunting licenses sold in the various counties, rather than the total population, the trends were essentially the same and need not be shown here.

An inspection of the 14 maps in figs. 9–22 shows that tularemia rates among humans in the south and central parts of the state are much higher than in the northern part. In each of these years there were blocks of counties in the south central region where the rates were 10 to 20 times as great as in the northeast part of the state. Areas of highest rates follow about the same pattern from year to year and are located in two general regions: (a) a region consisting of 15 to 25 counties in the southeast part of the state and (b) a region consisting of a smaller block of counties along the lower course of the Illinois River and up the west side of the state along the Mississippi River.

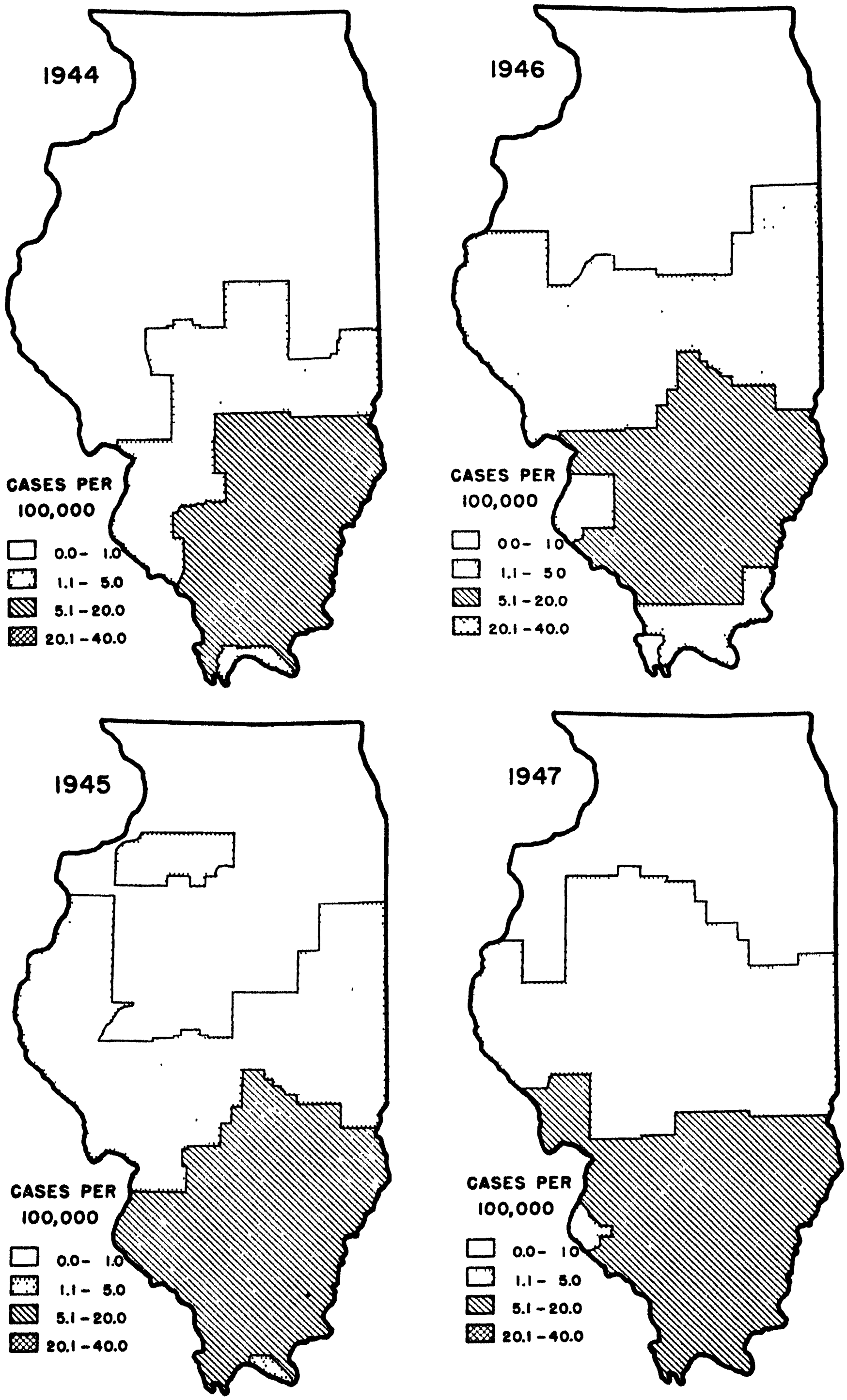
These regions correspond rather closely with the sections of the state listed by Case & Myers (1934) as having the highest percentages of idle land, that is, land not under cultivation. The first-named region consists for the most part of what is known as the gray soil prairie, where soils are light colored and fertility is relatively low.



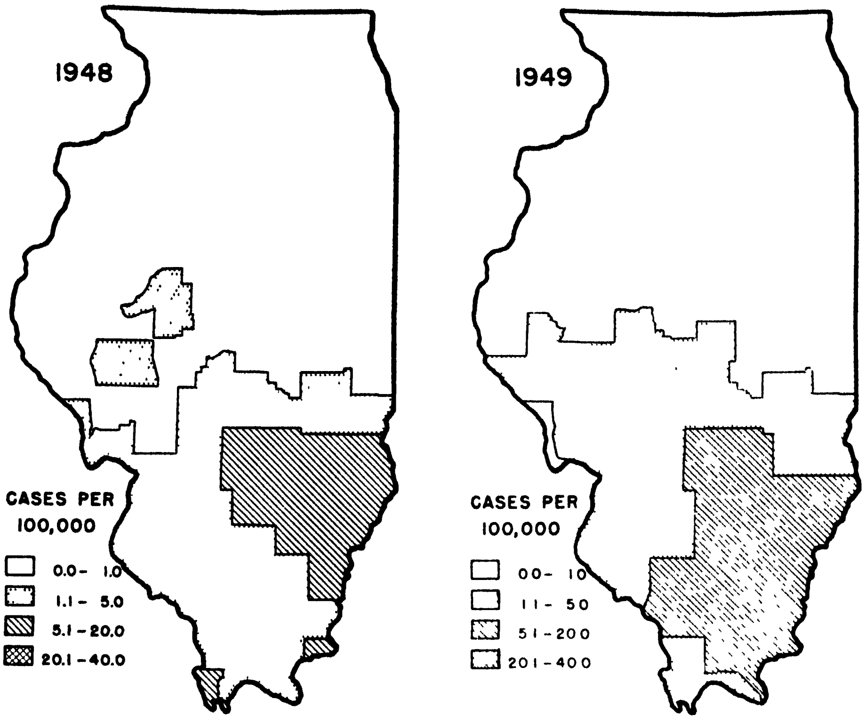
Figs. 9–12.—Distribution of human tularemia cases per 100,000 population in Illinois for the years 1936–1939.



Figs. 13–16.—Distribution of human tularemia cases per 100,000 population in Illinois for the years 1940–1943.



Figs. 17-20.—Distribution of human tularemia cases per 100,000 population in Illinois for the years 1944–1947.



Figs. 21–22.—Distribution of human tularemia cases per 100,000 population in Illinois for the years 1948–1949.

Here, there are scattered wood lots, overgrown stream banks, hedges, and, during periods of low agricultural prices, many fields that are allowed to lie fallow for one or more years at a time. The second region is dissected by a number of small streams draining into the Illinois and Mississippi rivers. As a result, it has a high percentage of forested and uncultivated land.

The tularemia rates in the above-named regions are among the highest in the United States. The prevalence of tularemia in these regions probably is indirectly related to the comparatively high rabbit populations found there. Green, Evans, & Larson's (1943) study of rabbit tick populations on snowshoe hares in Minnesota showed that when hares were abundant the average number of ticks per hare was high, but when hares were uncommon the average number was low. Possibly both the relatively high rabbit populations and dense ground cover in extensive areas of southern Illinois favor the survival of rabbit ticks, thus contributing to the spread of tularemia.

Weather and Tularemia

The interrelationships of ticks and tularemia to the cottontail and snowshoe hare in Minnesota were studied in detail for a number of years by the late Dr. Robert G. Green and his associates. They found that rabbit ticks were the principal means by which tularemia was spread from rabbit to rabbit in Minnesota and that these ticks left the rabbits by mid-autumn to go into hibernation. Green, Evans, & Larson (1943) reported that most hares and rabbits were found free of ticks after November 1, although occasional individuals might carry ticks in December, January, and even in February.

Green (1935, 1939) reported that after cold weather has caused the ticks to leave the rabbits, and after an additional week during which infected cottontails die, hunting is comparatively safe. He recommended that hunting in Minnesota be delayed until middle or late October.

Earlier in this paper it was pointed out that in 1938 there was a marked decline

in human tularemia in the northern Great Lakes states and a great increase in Illinois and states adjoining it on the east and west. In Illinois there was a considerable increase in the number of rabbits between the autumn of 1937 and the autumn of 1938, but it did not seem great enough to account for the eightfold increase in the number of tularemia cases reported in the 1938 hunting season. Inasmuch as there had been no shifts in the date of opening of the rabbit season in any of the North Central states, it occurred to us that these changes in tularemia rates might be due to differences in temperatures about the time of the opening of the season, as well as to changes in rabbit abundance.

Although the percentage of infected rabbits apparently declines sharply throughout the state soon after November 11 (the opening date of the rabbit-hunting seasons in recent years) the peak month for cases reported to the Illinois Department of Public Health is December, table 5. It should be explained here that tularemia cases are usually listed for the month in which they are reported and not the month of infection. Francis (1937) cites 45 Illinois tularemia cases for which the exact month of onset is accurately recorded, as follows: October, 1 case; November, 23 cases; December, 18 cases; and January, 1 case. We suppose that the apparent discrepancy arises from (a) delays between killing and eating rabbits (cold storage or freezing does not prevent infection), (b) incubation period for the infection, (c)

Table 5.—Distribution of Illinois cases of human tularemia, by months, 1926–1949.

MONTH	CASES	PER CENT OF TOTAL
July	57	1.9
August ...	50	1.6
September .	51	1.7
October	69	2.3
November	318	10.4
December	1,507	49.4
January...	603	19.8
February...	175	5.7
March	76	2.5
April.	46	1.5
May...	53	1.7
June...	46	1.5
Total....	*3,051*	*100.0*

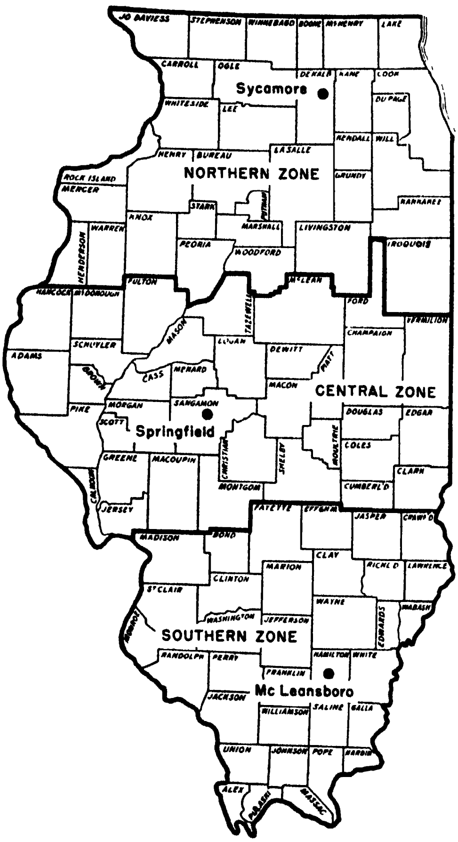


Fig. 23.—The three hunting zones of Illinois established by the state Game Code and the location of United States weather stations whose records were used in this paper as representative of each zone.

delay in consulting a physician, (d) time for making the diagnosis, and (e) time for making the report after diagnosis.

To learn whether the prevalence of human tularemia in Illinois is associated with temperatures preceding the opening of the rabbit season, we correlated the number of cases reported in the November-February period following the opening of each hunting season, 1926–1949, with the mean or average date of the first 10 freezing nights. A freezing night was defined arbitrarily as 27 degrees F. or colder. This method of studying the relation of the incidence of human tularemia to weather was devised several years ago by the writers (Anonymous 1941). It appears to result in a more satisfactory

correlation than any of several other methods that were tried.

Illinois, with a north-south length of almost 400 miles, has striking differences in climate, and for that reason the game and fish codes recognize three zones of about equal area: Northern, Central, and Southern. For making comparisons of the mean dates of the first 10 freezing nights, we chose a representative weather station located near the center of each of these zones. The Sycamore, Springfield, and McLeansboro stations have records covering long periods of years and are not in deep valleys or near large bodies of water. The three zones and the locations of these weather stations are shown in fig. 23.

When the numbers of days between the mean or average dates of these first 10 freezing nights and the dates of the opening of the rabbit-hunting seasons are compared with the numbers of cases of human tularemia for 24 successive years, 1926–1949, it is evident that there is a general correspondence in rises and falls between the two sets of data.

Table 6 shows the mean dates of the first 10 freezing nights for each zone in each of 24 autumns beginning in 1926, when tularemia was first reported in Illinois, as well as the opening dates of the rabbit-hunting season, the number of days between these dates in each year (the three zones averaged), and the numbers of tularemia cases in the November-February periods. The correspondence between the two curves is most striking in recent years, when recognition and reporting of the disease has been general, fig. 24.

For each year of the period 1936–1940, bracketing Illinois' greatest tularemia outbreak, data are available showing the distribution of cases by counties. These data make possible a comparison of average tula-

Table 6.—Dates of rabbit-hunting seasons, average or mean dates of first 10 freezing nights in autumn, and number of human tularemia cases reported in Illinois, 1926–1949. (N, C, and S indicate respectively the Northern, Central, and Southern hunting zones in Illinois as shown in fig. 23.)

Year	Hunting Season for Rabbits	Average Date of First 10 Freezing Nights (27° F. or Less)			Days After Opening of Season to Mean Date of First 10 Freezing Nights (Average for Three Zones)	Tularemia Cases Reported November–February
		N. Zone	C. Zone	S. Zone		
1926	Nov. 10–Jan. 31	Nov. 11	Nov. 17	Nov. 13	3.9	1
1927	Nov. 10–Jan. 31	Nov. 14	Nov. 25	Nov. 24	11.5	11
1928	Nov. 10–Jan. 31	Nov. 17	Dec. 4	Dec. 1	17.5	9
1929	Nov. 10–Jan. 31	Nov. 15	Nov. 26	Nov. 23	11.7	63
1930	Oct. 1–Jan. 10	Oct. 27	Nov. 9	Nov. 16	38.5	149
1931	Nov. 10–Jan. 31	Nov. 26	Dec. 23	Dec. 9	29.9	96
1932	Nov. 10–Jan. 31	Nov. 2	Nov. 16	Nov. 19	2.7	141
1933	Nov. 10–Jan. 31	Oct. 30	Nov. 14	Nov. 25	3.0	144
1934	Nov. 10–Jan. 31	Nov. 16	Dec. 9	Nov. 25	16.9	117
1935	(N) Nov. 10–Jan 31 (C) Nov. 20–Jan. 31 (S) Nov. 25–Jan. 31	Nov. 4	Nov. 25	Nov. 22	−1.2	34
1936	(N) Nov. 10–Jan. 31 (C) Nov. 20–Jan. 31 (S) Nov. 25–Jan. 31	Nov. 3	Nov. 23	Nov. 17	−3.5	103
1937	Nov. 10–Dec. 31	Oct. 27	Nov. 22	Nov. 10	−0.4	64
1938	Nov. 10–Dec. 31	Nov. 17	Dec. 1	Nov. 22	13.8	500
1939	Nov. 10–Jan. 15	Nov. 10	Dec. 12	Nov. 14	12.7	451
1940	Nov. 10–Jan. 15	Nov 9	Nov. 19	Nov. 18	6.2	164
1941	Nov. 10–Jan. 15	Nov. 18	Dec. 5	Nov. 27	16.9	70
1942	Nov. 10–Jan. 15	Oct. 23	Nov. 27	Nov. 14	1.6	40
1943	Nov. 11–Jan. 31	Nov. 9	Nov. 24	Nov. 20	7.5	24
1944	Nov. 11–Jan. 31	Nov. 5	Dec. 6	Dec. 8	15.7	132
1945	Nov. 11–Jan. 31	Nov. 9	Nov. 22	Nov. 29	9.9	60
1946	Nov. 11–Jan. 31	Nov. 21	Dec. 5	Dec. 3	19.1	121
1947	Nov. 11–Jan. 31	Nov. 12	Nov. 25	Nov. 29	11.6	35
1948	Nov. 11–Jan. 31	Nov. 12	Nov. 18	Dec. 8	12.1	41
1949	Nov. 11–Jan. 15	Nov. 9	Dec. 3	Nov. 29	13.2	58

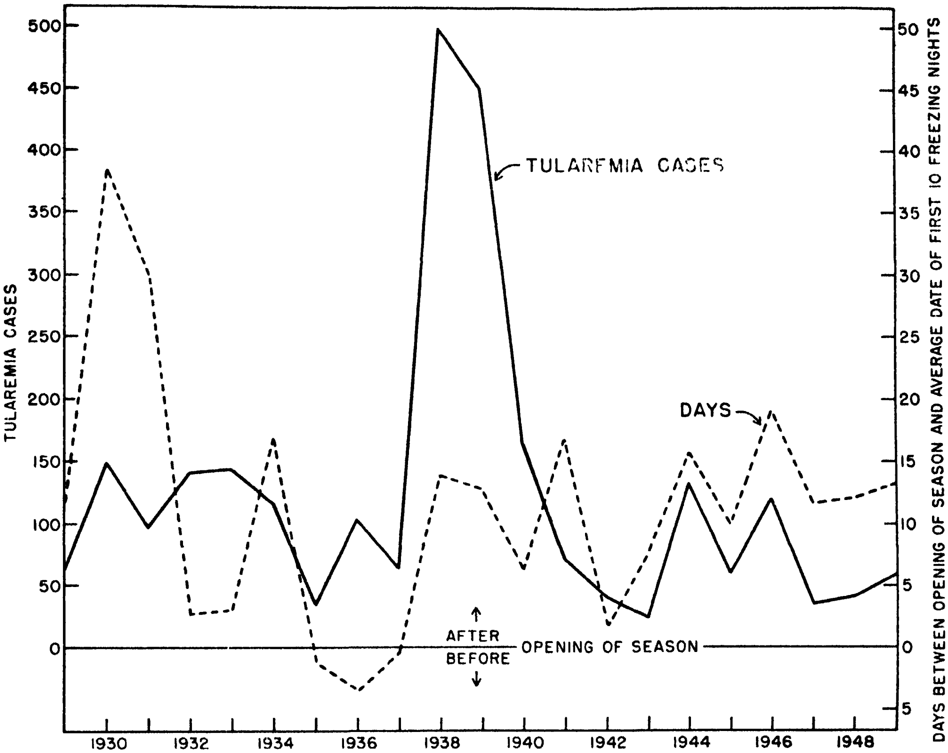


Fig. 24.—The number of cases of human tularemia per year in Illinois and the average date of the first 10 freezing nights in each autumn, 1929–1949.

remia rates in each of the three zones in each of those 5 years as they are related to the number of days between the opening date of the rabbit-hunting season and the mean date of the first 10 freezing nights. This 5-year period includes 1938 and 1939, when there was an epidemic of tularemia in Illinois, and 1936, 1937, and 1940, when the tularemia rate was about average. A summary is given in table 7.

Ecke's (1948) studies of ectoparasites on cottontails collected in central Illinois in the autumn of 1947 indicate that migration of rabbit ticks to hibernating places was at a peak in late October of that year and that the great majority of these ticks had left the rabbits to go into hibernation by the time of opening of the hunting season in early November. Temperatures were slightly above average in October and

Table 7.—Days from opening of rabbit-hunting season to average or mean date of first 10 freezing nights in autumn, number of hunting-zone-years represented, and tularemia rate in Illinois, 1936–1940. Figures on weather and human tularemia rate were obtained by averaging data for each zone separately.

Days From Opening of Rabbit-Hunting Season to Mean Date of First 10 Freezing Nights	Number of Zone-Years Averaged	Tularemia Rate, Cases per 100,000, November–February
30 to 39 days before.	1	14 1
20 to 29 days before. .	1	14 2
10 to 19 days before	2	11.1
0 to 9 days before .	7	4 3
0 to 9 days after .	3	1 0
10 to 19 days after . .	1	0.4

November of that year. It seems probable that even though tick hibernation in central Illinois is usually well advanced by November 11, the opening date of the rabbit-hunting season in recent years, it is not complete. It is apparent that this date is too early to afford hunters the desired freedom from the danger of infection. Hibernation of ticks may be delayed by recurrence or persistence of warm weather; presumably it occurs somewhat later in southern Illinois, where the majority of tularemia cases are found, than in the central and northern parts of the state.

Portman (1944) reported finding rabbit ticks feeding on cottontails in the southern counties of Missouri during the winters of 1943 and 1944. He believed that southern Missouri is the approximate northern limit of the rabbit tick's year-round activity. Since the extreme southern counties of Illinois are close to and in approximately the same latitude as the Missouri areas where Portman did his collecting, it is possible that a certain amount of year-round activity of ticks occurs there also.

Although a fair number of Illinois hunters now delay their rabbit hunting until cold weather, apparently a great many still begin to take rabbits as soon as the season opens, believing that the animals will soon be thinned out and made wary by other hunters. The initial rush greatly emphasizes the importance of the date of opening of the season because this is the critical period for tularemia. No statistics are available in Illinois showing how much hunting is concentrated in the early days of the season, but we estimate that between one-third and one-half of the year's crop is taken in the first week.

In Ohio, Benjamin (1940) reported the daily kill of rabbits in the season of 1939 on 180,000 acres of state-supervised hunting areas scattered through 35 counties. A quarter of the season's total was killed on the opening day (November 8), and by the end of the fourth day (November 11) more than half had been killed. Incidentally, he found that the average daily kill per hunter was about twice as great on the opening day as it was 3 or 4 weeks later.

Burroughs & Dayton (1941) reported the daily kill of cottontails on 9,000 acres in Saginaw County, Michigan, in 1938 and 1939. In both seasons combined, more than a third of the annual kill was made on the opening day and more than a half by the end of the first week.

All available evidence indicates that an early rabbit-hunting season, such as is now in effect in Illinois, results in the handling by hunters of approximately half of the rabbit kill at a time when the possibility of contracting the disease is still comparatively great.

Although it is apparent that temperatures just preceding the opening of the rabbit-hunting season play an important part in determining the amount of human tularemia in Illinois, the influence of weather, as has already been suggested, is frequently modified by another factor, the abundance of rabbits.

Rabbit Populations and Tularemia

The tularemia rate for the whole Central Region of the United States, fig. 6, increased from 9.8 cases per million inhabitants in 1937 to 27.3 cases per million in 1938 and 28.1 cases per million in 1939. The sharp rise in the tularemia rate during the period 1937–1939 occurred simultaneously with a marked increase in the numbers of cottontail rabbits in the Central Region, especially in the middle Mississippi and the lower Missouri river basins. Subsequently, following a general decrease of rabbits, the tularemia rate declined, and, by 1942, only 6.1 cases per million were reported in that region. This apparent relationship between the prevalence of tularemia and the high peak of rabbit populations emphasized the need for further information on the behavior of game populations.

Studies of animal populations in recent years have shown that many kinds of animals are subject to more or less regular variations in numbers. The snowshoe or varying hare, *Lepus americanus* Erxleben, is often cited as a classic example of an animal that undergoes cyclic fluctuations. MacLulich (1937) concluded from an analysis of population data, including records of the Hudson's Bay Company covering more than a century, that the cycles of the snowshoe hare in Canada have varied in length from 8 to 11 years and have averaged 9.6 years.

Although long-time population records,

such as have been used in studies of the snowshoe hare, are lacking for cottontail rabbits, records obtained by workers in several northern states indicate that cottontail populations tend to fluctuate rather widely. This paper does not attempt to arrive at final conclusions as to whether Illinois cottontail rabbits have cyclic, and thus possibly predictable, fluctuations. Nevertheless, it seems advisable to discuss briefly the available records of cottontail population trends in Illinois and nearby regions in recent years, because of the apparent relationship of the populations to the incidence of human tularemia.

Fig. 25 shows the annual kill of cottontails in Wisconsin during the period 1931–1949 as computed from hunters' reports to the Wisconsin Conservation Department (Anonymous 1949 and personal communication from W. E. Scott). Cottontail rabbits occur throughout Wisconsin except possibly in a narrow zone along the northern border, but they are generally most common in the southeastern counties (Morgan 1949). The curve in fig. 25 probably reflects the trend of the total Wisconsin cottontail rabbit population during the period 1931–1949. The trend of cottontail populations appears to have followed rather closely the trends of snowshoe hare and grouse populations in Wisconsin during the same period, as shown by Grange (1948).

Although the Illinois cottontail rabbit population data are not so nearly complete as the data for Wisconsin, records from the Natural History Survey and other sources have made possible a partial reconstruction of the fluctuations of cottontail rabbit populations in the state during 25 recent years. These data include, in addition to field notes and published records, replies of sportsmen to questionnaires, estimates of rabbit populations in southern Illinois by the United States Forest Service, information received annually by the Natural History Survey on rabbit damage to crops and orchards, and bag records and field notes of qualified hunter-observers. Because these data refer to different regions, they show something of the local aspects of population fluctuations in Illinois. As already indicated, local fluctuations are important in considering the relation of rabbit abundance to human tularemia rates.

The most noteworthy feature of the behavior of Illinois cottontail rabbit populations during the quarter century was the sharp increase in numbers during the late 1930's, culminating in 1938 and 1939 in the highest populations in many decades. The increase of rabbits in Illinois was most evident in the southern half of the state, where the main endemic centers of tularemia are found. As has been mentioned, nearly 1,000 cases of human tularemia were reported in Illinois during 1938 and 1939. Unusually high rabbit populations during these years were reported also in Iowa, Missouri, Kansas, Arkansas, and some other central states, where the tularemia rate also showed a sharp rise. Dur-

Table 8.—Number of rabbits flushed per square mile during pre-hunting-season game-bird censuses on the Jasper County, Illinois, study area, 4 square miles, 1936–1941.

YEAR	NUMBER OF RABBITS PER SQUARE MILE
1936	4.5
1937	3.8
1938	11.2
1939	14.2
1940	8.5
1941	3.3

Table 9.—Number of rabbits flushed per square mile during pre-hunting-season censuses made by the United States Forest Service on sample areas of the Shawnee National Forest, in southern Illinois, 1935–1949.

YEAR	NUMBER OF RABBITS PER SQUARE MILE
1935	54.5
1936	50.8
1937	64.6
1938	89.8
1939	82.3
1940	87.8
1941	77.4
1942	—
1943	—
1944	—
1945	159.6
1946	69.4
1947	79.0
1948	54.3
1949*	54.3

*The United States Forest Service discontinued its censuses after 1948. Its wildlife report for the North Central states in 1949 stated that rabbit populations on the Shawnee National Forest were unchanged from 1948 to 1949.

ing 1938 and 1939, counts of rabbits killed on highways in southern Illinois were approximately six times as high as they had been in immediately preceding years. Table 8, showing numbers of rabbits flushed during game-bird censuses made by the Illinois Natural History Survey on a 4-square-mile study area in Jasper County in southeastern Illinois, indicates the trend of rabbit populations there during the period 1936–1941.

Table 9 shows estimates of the number of rabbits per square mile in the Shawnee National Forest in extreme southern Illinois during the period 1935–1949; the estimates are based on counts made by the United States Forest Service on sample areas of the different forest types. No censusing was done during 1942–1944. The Forest Service data indicate that the trend of rabbit populations in southern Illinois was in many respects similar to the trend in central Illinois, fig. 26, but some differences are apparent. For example, rabbit populations were high in both central and southern Illinois about 1939 and 1945, but, in the central counties, the population peak of the mid-1940's was considerably smaller than that of 1939, fig. 26. Also, rabbit numbers in central Illinois increased in 1948 and 1949, while in the Shawnee National Forest they apparently remained low.

Population records for the dark soil prairie region of east central Illinois cover a longer period of years than those for any other section of the state. Fig. 26 indicates the population trend during the years 1925–1949. The curve is based on highway "kill" records in central and east central Illinois for several years, morning roadside counts of live rabbits in and near Champaign County, 1942–1949, and bag records and field notes since 1925 of Joe L. Mote of Watseka, Illinois.

Mr. Mote is a veteran hunter and a competent observer of wildlife. His rabbit-kill data are particularly valuable because they cover a longer period than do any other known Illinois records. For years when he was unable to hunt, his notes give information on the abundance of rabbits. Although his records are from a single locality in east central Illinois, the indicated fluctuations of rabbit populations agree quite closely with those shown by the records we have from other parts of central Illinois.

Rabbit populations are usually not exceptionally high in the dark soil prairie of central Illinois, and fluctuations are less pronounced there than in the southern counties. Nevertheless, it was observed during 15 recent years that general trends of rabbit populations in the central counties approximated those in the gray soil prairie of south central Illinois, where the cottontail rabbit populations were relatively high and where human tularemia was most prevalent.

As fig. 26 indicates, in recent years rabbit populations in central Illinois have shown major increases at intervals of about 10 years, with minor fluctuations between. It is of interest that in recent years population peaks of the prairie meadow mouse, *Microtus ochrogaster* (Wagner), in central Illinois have occurred there at approximately the same times as those of cottontail rabbits. Mohr (1947) mentions meadow-mouse highs in the winters of 1939–40, 1942–43, and 1945–46. According to an annual report by G. C. Oderkirk of the United States Fish and Wildlife Service, prairie meadow mice were exceedingly abundant in western and northern Illinois in the winter of 1946–47. In the autumn of 1949, members of the Natural History Survey staff found a recurrence of high meadow-mouse populations in the dark soil prairie of central and north central Illinois. Grange (1949) states, "Everything points to the fact, then, that Illinois Cottontails are geared to the Mouse cycle, and the cycle of Mouse-Rabbit predators." He does not discuss in detail the interrelationships of cottontail and mouse populations.

Field records indicate that, in Illinois, fluctuations of rabbit populations tend to be regional rather than state-wide. Differences in population trends frequently have been observed to be latitudinal. It may be noted by comparing figs. 25 and 26 that major population peaks in Wisconsin have not occurred during the same years as in central Illinois. Differences in the trends of cottontail populations probably account in large part for the previously mentioned differences in the trends of the tularemia rates in the Northern and Central regions of the United States.

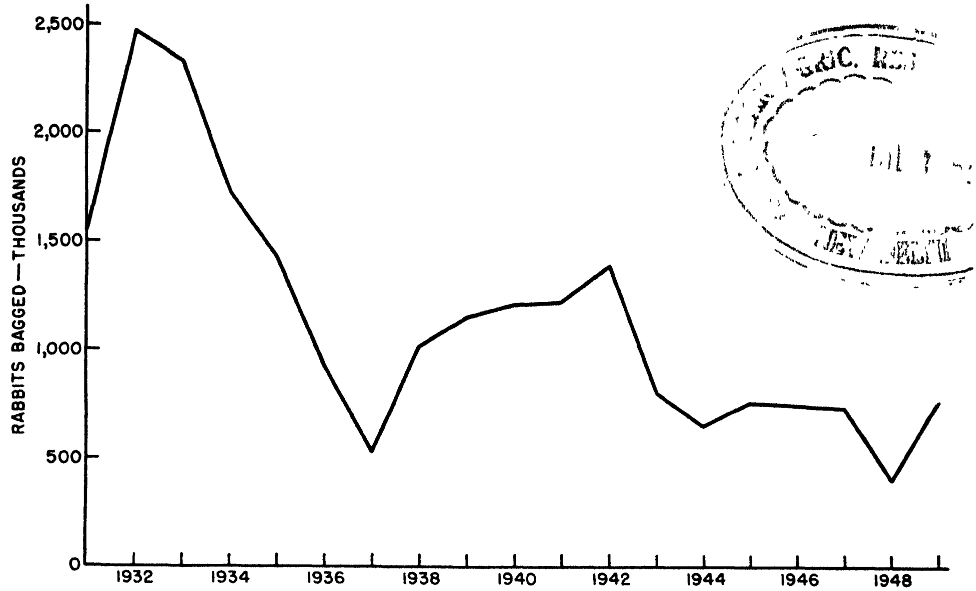


Fig. 25.—The calculated kill of cottontail rabbits per year in Wisconsin, 1931–1949. The basic data for this graph are from the Wisconsin Conservation Department.

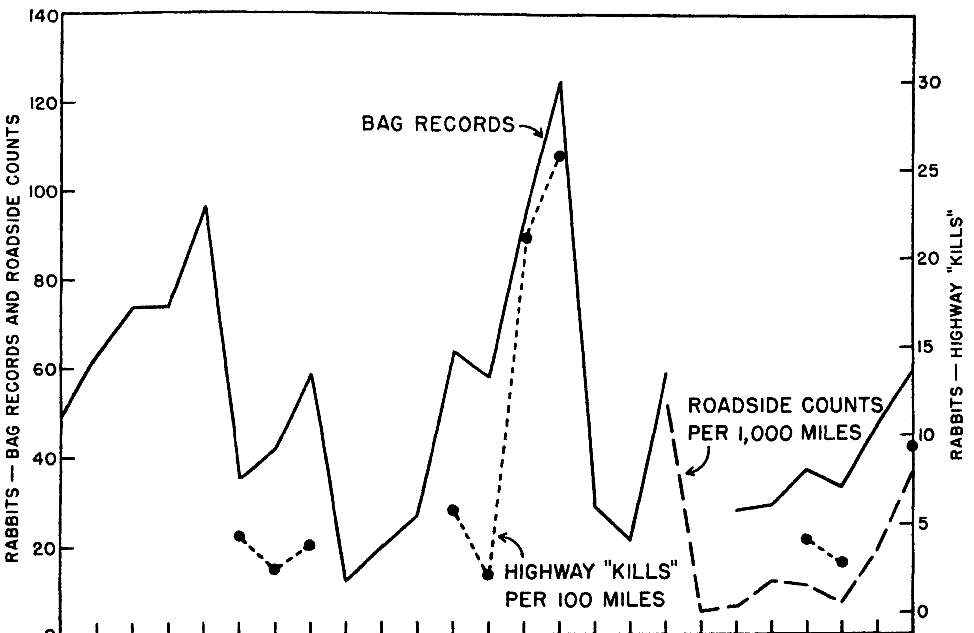


Fig. 26.—Cottontail rabbit population trends in central Illinois, 1925–1949, as indicated by bag records, highway "kill" counts, and roadside counts. Highway "kill" records for the years 1930–1932 are from Flint (1934) and for 1937 from Starrett (1938). The high rabbit populations of 1938 and 1939 were accompanied by a severe outbreak of human tularemia, fig. 24. Comparison of fig. 25 with fig. 26 indicates that major population peaks of rabbits did not occur in the same years in Wisconsin and central Illinois.

During periods of abnormally high rabbit populations, warm weather preceding the opening of the hunting season greatly increased the tularemia hazard in Illinois. In years when rabbit populations were unusually low, the tularemia rate remained low even during warm autumns, for example 1941, 1947, and 1948, fig. 24. When rabbit populations were average, the tularemia rate followed quite closely the curve of the mean date of the first 10 freezing autumn nights. Moderately high rabbit populations, such as occurred in the middle and late 1940's and probably in the early 1930's, brought increases in the number of human tularemia cases, but with these increases the disease did not reach epidemic proportions even during warm autumns.

Although there is evidence of more or less regular fluctuations in numbers of Illinois cottontails, our data do not indicate that many of these fluctuations are violent. The great population increase in 1938 and 1939 and the accompanying severe outbreak of human tularemia must be regarded as exceptional. Nevertheless, hunters should bear in mind that a sustained increase resulting in exceptionally high rabbit populations in their hunting areas may in turn favor a severe outbreak of tularemia among the rabbits.

At times, tularemia may be a factor that contributes to the decline of rabbit numbers following population peaks. Local tularemia outbreaks that were the apparent cause of reduction of cottontail populations from high to low levels have been reported by Waller (1940) and Hendrickson (1943) in Iowa, Hicks (1942) in Ohio, and others. It seems safe to assume, however, that tularemia is but one of numerous factors that contribute to population control among cottontails.

Tularemia and the Rabbit Hunter

Green (1942) has pointed out that tularemia is in large part a hunter's problem. This observation seems applicable to Illinois especially. At present, between 400,000 and 500,000 licensed sportsmen hunt annually in Illinois. In addition, many thousands of boys and men hunt on their home farms without being required to purchase hunting licenses. The great majority of these people confine their hunting entirely to upland game. Although many of the Illinois hunters now refuse to bag cottontails for fear of contracting tularemia, most of them depend largely on rabbit hunting for their sport.

The importance of the cottontail rabbit as a game species in Illinois will be evident when it is considered that rabbits can be found on virtually every square mile of farm land in the state and in most cities and towns, and that they are usually present in huntable numbers through the open season, even in intensively cultivated districts. All other resident game species tend to be local in distribution. Because cottontails can be found close to home by most Illinois hunters, which makes hunting them a relatively inexpensive recreation, and because they have desirable sporting and table qualities, these rabbits in recent years have averaged more than one-half of the number of game animals taken annually by the hunters of the state.

Cottontail rabbits have usually increased in numbers readily under wildlife habitat improvement programs that have been conducted in Illinois. This tendency was illustrated on the Urbana Township Wildlife Area by the marked rise of rabbit populations, noted by the senior author, that accompanied the growth of hedges and blocks of shrubs and trees during the years following planting on the area about 10 years ago. In favorable habitats, rabbits usually can be hunted heavily year after year without permanent reduction of their population levels (Pirnie 1949). In fact, heavy hunting may be a desirable game management measure to reduce temporarily the population levels of rabbits and thereby lessen the danger of epizootics.

It seems highly desirable for hunters in Illinois and other states where rabbits are important as game to have reliable information on how best to avoid contracting tularemia while hunting. The medical profession has recently made marked progress in successfully combating the disease in man. Wildlife research workers and game administrators in many states undoubtedly can contribute materially to the solution of the tularemia problem by determining hunting practices and hunting seasons likely to afford the greatest protection to hunters.

Green (1942) observed that tularemia in rabbits and hares in Minnesota was chiefly a spring and fall disease. He found infection to be relatively uncommon in these animals during the summer months and very rare during the winter. On the basis of the observed decline of tularemia in winter, he had previously (1935, 1939) urged delay of rabbit hunting until after the onset of cold weather.

In describing tularemia in rabbits, Green (1942) stated, "Tularemia is a bacterial disease; that is, it is caused by a microbe which can be seen under an ordinary microscope. The germ can be grown in the laboratory and is easily recognized by a trained bacteriologist. When this germ infects an animal, particularly a rabbit, it grows in the blood stream and in all the internal organs of the animal and produces the disease which we call tularemia.

"When an infected rabbit is encountered in the woods, its reactions are usually slow and the animal appears somewhat tame. Regardless of tularemia, it is always best to take only rabbits or other wild animals that show vigor and can be taken only with difficulty.

"The typical infection as found in a rabbit can be recognized by a peppering of tiny white spots on the liver and spleen. The white spots are abscesses caused by growth of the germ in those organs. The infection is of relatively short duration in rabbits and hares, usually lasting about seven days. Cottontail rabbits are very susceptible and always die; snowshoe hares are comparatively resistant and usually recover.

. . . .

"On cleaning a rabbit, if the reddish-brown liver or spleen is seen to be peppered with fine white spots, the carcass should be burned, one's hands should be repeatedly washed with soap and water and finally, if possible, with a disinfectant. Any cuts on the hands should be treated with iodine."

Inasmuch as other conditions than tularemia may cause spotting of the liver or other internal organs, figs. 27 and 28, this symptom is not conclusive evidence of the

Fig. 27.—Lesions of tularemia on liver and spleen of a domestic rabbit, following experimental infection. The small white spots become visible on the liver and spleen about the third day of illness. Photo by Nick Kramis, photographer, Rocky Mountain Laboratory, United States Public Health Service.

disease in rabbits. Fig. 27 illustrates the characteristic appearance of the liver and spleen of a rabbit infected with tularemia. Tapeworm cysts are found rather frequently in the muscles or attached to internal organs of Illinois cottontail rabbits. These cysts are not related to tularemia and are harmless unless eaten raw, but it is better to discard an affected rabbit rather than to try to cut out the cysts.

It should be borne in mind that rabbits and other game may not exhibit visible symptoms of tularemia in early stages of the disease. Francis (1937) stated of infected rabbits that "innumerable small round spots [on the liver] become plainly visible on the third or fourth day of illness, but these spots are too small to be seen on the first and second days of illness. Therefore, if a rabbit is shot on the first or second day of illness the liver, though diseased, will appear healthy." Because it is possible for infection to be present in apparently healthy animals, thorough cooking of all game is always a wise precaution. Tularemia contracted by humans as a result of eating infected game that is insufficiently cooked appears to be especially severe and is associated with a high death rate. Cooking of rabbits and other game until the bone marrow and the meat surrounding the bones are well done eliminates any danger of tularemia infection.

A number of organizations have advised hunters to wear rubber gloves when handling cottontails. Yeatter & Thompson (1943) have pointed out that this precaution, although probably offering a degree of protection, is not entirely practical and may give a false sense of security to hunters during tularemia epidemics. The hunter usually is bare handed when handling the gun, and during a day of hunting receives scratches from briers or barbed wire, or becomes chafed on the hands or wrists. In addition, as has been mentioned, considerable evidence indicates that infection can take place through the unbroken skin.

Although some hunters in recent years have put on cotton or leather gloves before picking up rabbits, they are probably in the minority. Every shot rabbit is smeared with blood, and, whether the animal is

Fig. 28.—Lesions of tularemia on lungs of a domestic rabbit, following experimental infection. Photo by Nick Kramis, photographer, Rocky Mountain Laboratory, United States Public Health Service.

carried in the hand or placed in a hunting coat, it may come in contact with the skin. Rubber gloves are not commonly used by hunters in the field, and, even though an attempt is made to use them while cleaning rabbits, there are several points of danger. The gloves may not be of sufficiently good quality, but, more important, the average hunter probably does not possess the training and skill required to use the gloves without puncturing them or to remove and sterilize them without contaminating the hands or face. Many laboratory technicians and medical workers have contracted tularemia even when all available facilities and known protective measures have been employed. Therefore, it is unlikely that rubber gloves alone offer the untrained layman much protection.

Although it would obviously be unwise to minimize tularemia as a hunting hazard, it should be pointed out that publicity given the disease by newspapers and radio has tended to instill in the public an exaggerated fear of becoming infected by handling wild rabbits during nonepidemic years or during late fall or winter months. The writers (Yeatter & Thompson 1943) have stated in this regard, "Tularemia is a serious disease and it is not our intention to underrate it, but it has been mostly a mental hazard since the peak years. The danger from car accidents and gun accidents, which is considerably greater, does not keep people from hunting. For example, in 1942, Illinois had 67 cases and one death from tularemia. In the same year Wisconsin, with almost the same number of licensed hunters had 109 gun accidents and 36 deaths. Comparable figures are not available for Illinois, but they are probably about the same as those for Wisconsin because 80 of the accidents and 24 of the deaths came during the small game season."

Hicks (1942), in recommending that the rabbit-hunting season in Ohio be delayed until December, pointed out that the delay in opening of the season would minimize the frequency of human tularemia and eliminate much of the psychological hazard which then detracted greatly from the pleasures of hunting in Ohio.

Hunters are not likely to follow elaborate precautions for handling rabbits skillfully enough to protect themselves from infection with tularemia. The writers believe that Illinois hunters can most effectively reduce the tularemia hazard to a minimum by delaying rabbit hunting until after the onset of sharp, freezing weather. This delay is urged especially for hunters in the Central and Southern zones of the state, where rabbit ticks presumably are active later in the fall than in the Northern Zone. It should be remembered that periods of exceptionally high rabbit populations, such as occurred in Illinois in 1938 and 1939, increase the danger of infection and call for special measures on the part of hunters.

Within the past decade, methods of treating tularemia in humans have been improved greatly, principally through the use of antibiotics. The United States Fish and Wildlife Service Wildlife Leaflet 271 (Anonymous 1948) stated in regard to the use of streptomycin in treating tularemia, "Many remarkable recoveries with few failures . . . . have been recorded following the use of this agent." Recently aureomycin and chloromycin have largely supplanted streptomycin in the treatment of tularemia. Probably the low death rate in Illinois in recent years, table 4, reflects the increasing use of antibiotics in treatment of the disease.

Recommendations

Detailed analysis of weather and tularemia records indicates that delaying the opening of the rabbit season until December is the most practical method for reducing tularemia in Illinois. Recommendation is therefore made that the opening date be changed to December 1 or, preferably, December 8, at least in the Central and Southern zones of the state. The opening date in the Northern Zone might, without serious hazard in most years, continue to be November 11. The gains to be expected from standpoints of public health and enjoyment of hunting seem to far outweigh any disadvantages that might arise from this proposed change in the game code. To compensate for the delay of the opening date, the rabbit season could be extended to January 30.

Because of its adaptability to farm habitats throughout Illinois, the cottontail rabbit is undoubtedly our most impor-

Fig. 29.—Illinois Natural History Survey entomologist examining wild cottontail rabbit for external parasites.

tant game animal. There are, however, a number of questions that need to be answered before the best use of this game animal can be made. Studies of population fluctuations should be continued, and records of long-time censuses on areas that are representative of the different sections of the state should be analyzed to give better methods for predicting population trends and possible disease outbreaks.

Studies should be made to supplement the investigations begun by Ecke (1948) for the Natural History Survey—studies involving the degree of infestation of rabbits by ticks and other tularemia vectors, fig. 29, the per cent of diseased animals, numbers of embryos per female, numbers of broods of young per female, weights, food, and other phases of the life cycle. The relation of tularemia and its vectors to rabbits, and to other wild and domestic animals, should be further examined.

It seems evident from tularemia studies already completed that much progress in controlling the disease can be made by enacting legislation for confining the hunting season to the colder months of the year, by educating hunters to take adequate safeguards, and by warning the public of any significant increases in the tularemia hazard. In event that exceptional conditions arise, such as those in 1938 and 1939, it is suggested that the Illinois Department of Public Health, the Illinois Department of Conservation, and the Illinois Natural History Survey, working

jointly, bring such an emergency to the attention of the governor of the state so that he may by proclamation defer the opening of the rabbit-hunting season until after the principal danger has passed.

Summary

1. An analysis of the human tularemia records of the United States Department of Public Health indicates that, on the basis of tularemia rates and seasonal incidence of the disease, the United States falls into four general regions, namely, Northern, Central, Southern, and Western.

2. In a 24-year period beginning in 1926, Illinois had about twice as many reported human tularemia cases as any other state. The great majority of these reported cases was among residents of the southern half of the state.

3. The high incidence of tularemia among hunters, their families, and others in southern Illinois appears to be related to the greater abundance of rabbits in that region.

4. The human tularemia rate in any year in Illinois seems to be determined both by temperatures about the time of the opening of the rabbit season and by the abundance of rabbits. Very high rabbit populations increase the tularemia hazard.

5. When rabbit populations were average, the human tularemia rates followed the curve of the mean or average date of the first 10 freezing autumn nights. When rabbit populations were low, the tularemia rates remained low, even during warm autumns. The most serious outbreak of human tularemia known in the past half century was in 1938 and 1939 when rabbit populations were exceedingly high and the autumns warm until well past the opening date of the season.

6. Delay in the opening of the rabbit-hunting season until December 1, particularly in the Central and Southern zones of Illinois, is recommended as the most practical management method for reducing the amount of human tularemia. The Northern Zone may, without serious hazard in most years, continue to open on November 11.

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